TITLE: UAVs - Current Situation and Considerations for the Way Forward

UAVs — CURRENT SITUATION AND CONSIDERATIONS FOR THE WAY FORWARD

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This document will try to give the reader an overview of the current situation pertaining to unmanned aerial vehicle (UAV) systems in the world and it is will endeavour to give some indications on what the future may have in store for us. It does not have the pretention of being complete and covering everything going on in this field in every country, but rather it will try to give a representative overview of the UAVs currently in use, being considered for purchase and the general state of UAV-related technology and the industry involved.

PREAMBLE & DEFINITION

At the onset, it is considered worthwhile to try to define what is meant by the term UAV, therewith hopefully avoiding any misunderstandings.

> **UAVs are to be understood as uninhabited and reuseable motorized aerial vehicles, which are remotely controlled, semi-autonomous, autonomous, or have a combination of these capabilities, and that can carry various types of payloads, making them capable of performing specific tasks within the earth's atmosphere, or beyond, for a duration, which is related to their missions.**

This broad definition permits to encompass fixed and rotary wing UAVs, lighter-than-air UAVs, lethal aerial vehicles (training rounds without warheads), aerial decoys, aerial targets, alternatively piloted aircraft and uninhabited combat aerial vehicles, therewith highlighting the fact that these systems have a certain number of common features, offer the potential for cross-over technology, and utilize or will utilize similar technologies.

However, the separation line with cruise missiles is not really clear; indeed, it has been argued that cruise missiles are actually UAVs. This overview will not include cruise missiles, and will only sideways refer to aerial target vehicle systems.

Figure I		UAV CLASSIFICATION		
CATEGORIES	ABBR.	RANGE km	FL. ALT. m	ENDURANCE hours
		TACTICAL UAVs		
Micro	µ	< 10	250	1
Mini	MINI	< 10	350	< 2
Close Range	CR	10 - 30	3.000	2 - 4
Short Range	SR	30 - 70	3.000	3 - 6
Medium Range	MR	70 - 200	3/5.000	6 - 10
MR Endurance	MRE	> 500	5 - 8.000	10 - 18
Low Altitude Deep Penetration	LADP	> 250	50 - 9.000	0,5 - 1
Low Alt. Endurance	LAE	> 500	3.000	> 24
Medium Altitude Long Endurance	MALE	> 500	5 - 8.000	24 - 48
		STRATEGIC UAVs		
High Altitude Long Endurance	HALE	> 1000	15 - 20.000	24 - 48
Uninhabited Combat Aerial Vehicles	UCAV	+/- 400	< 20.000	+/- 2
		SPECIAL TASK UAVs		
Offensive	LETH	300	3 - 4.000	3 - 4
Decoys	DEC	0-500	50 - 5.000	up to 4

The classification and abbreviations indicated in Figure I, will be used and referred to in this document. Range, as indicated in Figures I and II should be understood as the operational range (LOS and/or SAT/COM) of the uplink (command & control) and downlink (telemetry & imagery). There are a number of other parameters, such as flight altitude, launch & recovery methods, that can be used to further classify UAVs. For purposes of clarity, the classification of Special Task UAVs has been added.

A general review, taking the aforementioned into account, and supplying examples in each category, can be found in Figure III.

GENERAL SITUATIONAL OVERVIEW

Up to now, funding for the development of UAVs has principally been put up by the military and this is expected to remain so for the foreseeable future. Eventhough UAVs have been around, in one form or another for nearly 50 years, their military value and complementarity in relation to other weapon systems has, until recently, not been generally acknowledged and accepted by the military hierarchy and the political establishment until fairly recently.

The successful deployment of UAVs during the Gulf War was instrumental in making the international military hierarchy conscious of the actual merits of UAVs and the various roles they could be used for. Thanks to CNN, it was also the first time that the use of UAVs was brought to the attention of the politicians and the general public. During this conflict, tactical UAVs were deployed (Exdrone/USA, Pointer/USA, Pioneer/USA, Mart/France) and tactical decoys were used (Chukar/USA & TALD/Israel, both by the USA). The Phoenix UAV (GEC-Marconi) was sent to the Gulf, but did not make it in time to be deployed before the end of the conflict.

The more recent and successful deployments of UAVs over Bosnia and Kosovo (CL289 by France & Germany; Pheonix by UK; Hunter, GNAT, Pioneer and Predator by USA) have greatly contributed to the wider acceptance and recognition of the value of UAVs.

It is commonly stated that UAVs are used for missions that are «dull, dirty and dangerous». This refers to missions which would generally be long, tiring, and in some cases boring, for aircraft pilots, and which would present a high risk factor for pilots. After initial grumblings by air force personnel, the use of UAVs is increasingly being considered as complementary to missions by piloted aircraft. This has resulted in the recognition and acceptance of the value of UAVs by pilots, which has without any doubt positively contributed to the development of medium and high altitude (MALE & HALE) UAVs. These UAV systems can be used for surveillance or treaty monitoring purposes, as well as battle damage assessment, over hostile and heavily defended areas, where a downed

Figure II UNINHABITED AERIAL VEHICLE SYSTEM CLASSIFICATION													
TACTICAL											STRATEGIC		
LETH	Decoy	Micro	Mini	CR	SR	MR	MRE	LADP	MALE	LAE	UCAV	HALE	
		X	X	X	X	X							Rotary Wing
X	X	X	X	X	X	X	X	X	X	X	X	X	Fixed Wing
		X	X	X	X								Light-Than-Air
					X	X		X	X	X	X	X	Optionally Piloted
Hand-, Weapon-, Air-launched, Launcher, VTOL, RATO										Wheels			Launch Method
		Skids, Net, Parachute (+ Airbags), VTOL, Wheels								Wheels			Recovery Method

pilot would not only risk his own life, but could also risk the lifes of the extraction team, or, if caught, could even become a political liability to the government of his country, or the alliance his country is a member of.

In many cases, the development of UAVs has been hampered by ever-changing military requirements, which resulted in them being forced to fulfill multiple roles. The problems encountered by the money guzzling US Aquila and Outrider programmes can be traced back to this problem. It is now recognized that it is impossible to produce a single UAV that can fulfill all roles. Most UAVs in operation today still reflect a large degree of «customized uniqueness», which can be linked to the system's first customer, and restricts the system's potential with another military customers.

Military forces are now mostly considering families of complementary UAVs in both the tactical and the strategic categories, with the Army in most cases responsible for tactical and the Air Force for the strategic assets. With the advent of VTOL UAVs, the Navy is also starting to show keen interest. However, a special mention should be made of the experience AAI Corp., USA has in the field of ship-launched (RATO) fixed wing UAVs. AAI Corp. has been involved with the Pioneer UAV from the onset, and has not only been responsible for the majority of the very many upgrades that have been made of the years, but also gained valuable operational experience during the Gulf War, when they established a forward base in Bahrain from where they serviced and reconditioned Pioneer UAVs, which were extensively launched from land-based bases, as well as from ships. Their ship-launch experience with Pioneer has made it possible for AAI Corp. to develop, within a very short period of time, in reply to a requirement of the South Korean Navy, the fixed wing Shadow 400 (range: 200 km), which is ship-launched (by means of RATO) and ship-recoverable (by means of a recovery net on the rear deck).

Today, there is a clear tendancy to develop UAVs directed at fulfilling specific missions. Specialization is the name of the game. This however does not always mean that totally new systems have to be developed. There is a clear trend towards to making UAVs modular: by changing payloads, the same aerial vehicle can fulfill another function. This however sounds easier than it is.

VTOL UAVs are currently being looked at for airborne (military & humanitarian) mine detection purposes (France, Germany, Netherlands, UK, USA) on land and in the littoral area, as well as for urban warfare roles, perimetric surveillance purposes, helicopter flight path reconnaissance, and UGV command and control relay.

The arrival of shipborne VTOL UAVs is starting to be seen on the horizon; these systems will most probably be initially deployed in the USA, where the US NAvy conducted a technology maturity evaluation in 1998, which continues in its second phase in 1999. It should be noted that there is a clearly defined future requirement for shipborne VTOL UAVs for various roles on upcoming new generation NATO frigates.

Interest in VTOL aerial targets capable of realistically simulating popping up attack helicopters (for weapon system evaluation and AAA training) is also growing, as is manifested by Bristol Aerospace's Hokum-X programme with the US Army Targets Management Office.

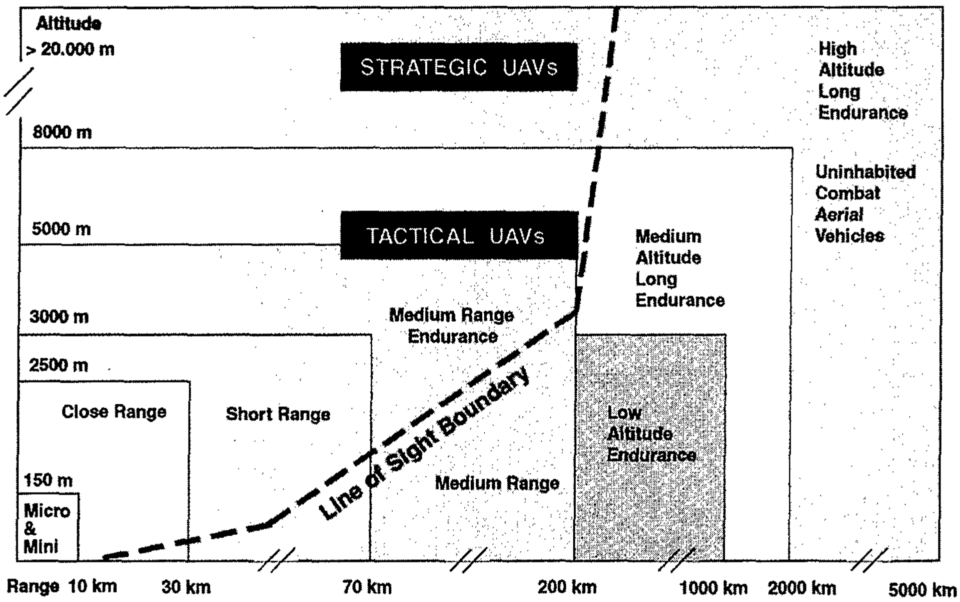
VTOL UAVs are also being used for an ever-growing number of civilian applications. Japan has been extremely active in agricultural applications; well over a

	RANGE	ENDUR-ANCE	FLIGHT ALT. (Max)	LAUNCH METHOD	RECOVERY METHOD
Category	kms	hours	meters		
		TACTICAL UAVS			
MICRO µ	< 10	< 1	250	By Hand H-HL, WL VTOL +	Belly, skids
Missions Examples	RSTA, comms relay, scouting, NBC sampling, EW MicroStar, Hyperav+, Black Widow, Microbat				
MINI	< 10	< 2	350	H-HL, L VTOL + Wheels	Belly, skids Wheels Parachute
Missions Examples	Film industry, broadcast industry, agriculture, pollution measurement, powerline verification, mine detection Aerocam, RPH2+, R50+, RMax+, SurveyCopter				
CR	10 - 30	2 - 4	3000	H-HL, L VTOL + Wheels	Belly, skids Wheels Parachute
Missions Examples	Recon, EW, artillery correction, mine detection, crop survey, search & rescue APID+, Camcopter+, Cypher+, Dragon/Exdrone, Javelin, LUNA, Mini-Tucan, Backpack, Observer, Pointer, Vigilant, Vigiplane				
SR	30 - 70	3 - 6	3000	L VTOL + RATO	Belly-skids Parachute Para/airbag
Missions Examples	RSTA, BDA, EW, NBC sampling, mine detection, wildlife research, mineral prospection Crecerelle, Dragon, EyeView, Fox, Heliot+, Mirach 26, Nishant, Phantom, Phoenix, Sentry, Sojka, Vulture				
MR	70 - 200	6 - 10	3 - 5000	L, VTOL + Wheels RATO	Skids Wheels Para/airbag
Missions Examples	RSTA, BDA, artillery correction, EW, NBC sampling, mine detection, comms relay Brevel (KZD), CL327+, Eagle Eye+, Hunter B, Mücke, Outrider, Pioneer, Prowler, Ranger, Searcher, Seeker, Shadow 200, Shadow 400, SkyEye, Sniper, Sperwer				
MRE	1000	10 - 18	5/8000	Wheels RATO	Wheels
Missions Example	RSTA, BDA, comms relay Hermes 450S, Prowler II, Searcher II, Shadow 600, S.Vultre				
LADP	> 250	0,5 - 1	50 - 9000	RATO	Para/airbag
Missions Examples	Recon CL89, CL289, Mirach 100, Mirach 150				
LAE	> 500	> 24	3000	Wheels Launcher °	Wheels Para/airbag
Missions Examples	Meteorological sensing Aerosonde °, Laima, Pelican (Optionally piloted aircraft)				
		OFFENSIVE UAVs			
LETHAL	300	3- 4	3 - 4000	Launcher RATO Air-launch •	Expendable
Missions Examples	Anti-tank/vehicle, anti-radar, anti-infrastructure, anti-ship Harpy, K100, Lark, Marula, Polyphem, Taifun, Sea Ferret •				
MALE	500-750	24 - 48	5 - 8000	R-L.G.	R-L.G.
Missions Examples	RSTA, BDA, comms relay, EW, weapons delivery Altus, Hermes 1500, Heron (EagleStar), I.GNAT, Perseus, Predator, Theseus				
		STRATEGIC UAVS			
UCAV	+/- 400	+/- 2	< 20.000	Wheels	Wheels
Missions	SEAD, Air-to-air combat				
HALE	1 - 6000	24 - 48	15-20.000	R-L.G.	R-L.G.
Missions Examples	RSTA, BDA, comms relay, EW, boost phase intercept missile launch vehicle Darkstar, Global Hawk, Raptor, Condor				
		DECOYS			
DECOYS	0 - 500	a few min. to several hours	50 - 5000	Canister * RATO Air-launch	Expendable
Missions Examples	Aerial & naval decoys Chukar, Delilah, Flyrt, MALD, Nulka *, TALD				

EXPLANATIONS

H : Hand-launched
H-HL : Hand-held launcher
L : Launcher W : Wheels
VTOL : Vertical Take-Off & Landing
RATO : Rocket assisted Take-Off
RSTA : Recon, Surveillance, Target Acquisition
EW : Electronic Warfare
BDA : Battle Damage Assessmt
R-L.G. : Retractible landing gear

Figure IV CLASSIFICATION BY RANGE & ALTITUDE



2000 VTOL UAVs (all produced in Japan) and with payload capabilities varying from 25 to 150 kg, have been sold for crop spraying, fertilizing and seading purposes in Japan. There are over 4500 licenced commercial UAV operators in Japan. South Korea is now also producing a VTOL UAV for agricultural applications.

When one considers the combined use of various UAVs by NATO nations, interoperability (operating different UAVs in the same theatre of operations, operating different UAVs through the same ground control station and/or receiving data different UAVs at non-system specific terminals) rapidly becomes an issue. Joint intervention and peacekeeping or treaty monitoring operations within a UN- or NATO-instigated coalition are other drivers in this direction and are making their influence felt in the area of command & control and datalink (frequency) standardization, which is being addressed by a number of NATO agencies, commitees and working groups.

Currently, UAVs are principally being tasked with surveillance & monitoring, target location, reconnaissance and battle damage assessment. In most cases, UAVs are only as good as the payloads they carry. Tremendous technological advances have been made in this area over the last few years. Imaging payloads are getting ever smaller and more powerful and all-weather capability is finally becoming a reality. Synthetic aperture radars (SAR) are starting to become operational (TSAR on Predator, HISAR on Global Hawk) and are being downsized to be able to fit into tactical UAVs (SWORD programme for the CL289; Lynx development for Prowler II). Various types of payloads for chemical and biological sensing are being experimented with; airborne land and sea mine detection sensors, as well as various EW packages are also under development in various countries.

It is increasingly clear that UAVs will be, and in some cases already are, a critical part in the military information chain. They are emerging as the next generation of airborne reconnaissance, thanks to their ability to penetrate enemy airspace and dwell over or near target areas, and detect, identify, and track hostile activity in sufficient time to target lethal weapon systems or manouevre against or around them, and conduct battle damage assessment, or with the advent of foilage penetrating radar, see through multiple canopy jungles. They are the ideal tool in the rapidly moving battlefield of the end of the 20th and the beginning of the 21st century. The air-transportability of most UAV systems makes them rapidly deployable to mission staging areas all around the world.

UAVs with limited performance capabilities are relatively easy and inexpensive to produce, using readily available commercial off-the-shelf components,and because an evergrowing number of countries are deploying or trying to deploy them UAVs are now being recognized by NATO and most advanced countries as a serious threat, against which its forces have to be trained. This fact explains the upcoming requirement with the US Army for aerial targets capable of realistically simulating specific UAVs, as well as the emerging interest in low-cost simple UAVs with limited imagery capabilities to be used to train the soldior in the field to constantly be on the alert for UAVs.

Autonomous offensive UAVs with radiation seeker heads, such as the Harpy (IAI, Israel), K100 (CAC Systèmes, France), Lark (Kentron, South Africa) could start to experience increased demand due to the requirement to defeat ever more sophisticated air defence radars. One of the largest European UAV development contracts recently awarded was for the Taifun offensive UAV (STN Atlas Elektronik, Germany), which, equipped with a radar-based seeker head (Dornier, Germany) and an automatic onboard target recognition capability, is being developed to attack vehicles, strategic structures, as well as radar sites.

The commercial use of UAVs could have a beneficial effect on the use of military UAVs, as economies of scale would then become possible in certain areas. The commercial use of UAVs is not only being severely limited by air traffic management issues and high acquisition costs, but also by the high price of ownership and insurance (in relation to manned aircraft). The high cost of insurance severely limits the interest of leasing UAV systems for commercial (or military applications). The excessive cost of insurance is generally attributed to the unproven reliability (safety) of UAVs; once UAV technology has proven itself a little more, and acceptable UAV system qualification norms exist, their cost should come down.

The attrition rates for UAVs (all categories) are still relatively high in comparision with those of manned aircraft, and weigh rather heavily on the system's operational cost. Most UAV mishaps tend to occur during the launch and recovery phases. This in turn, is motivating authorities to increasingly specify automatic launch (take-off) and recovery systems for their future

requirements.

Dual redundancy is becoming more common, and in some cases, is already being imposed by the military customers.

UAV and payload operator training is currently still principally accomplished by flying. This will have to change and simulator-based training will without any doubt become more and more important. However, the few training simulators that exist are principally system specific (and therefore expensive) and do not permit the training of operators for various other types of UAV systems. Simulator training is bound to be cheaper, increase operation proficiency, without the material risks associated with flying (attrition), and will be totally independant of weather conditions and the current restrictions imposed by the air traffic management authorities.

The commercial use of UAVs is still in its infant shoes and principally concerns small and very short range VTOL UAVs and lighter-than-air (dirigible) UAVs, which are flown in-sight (motion picture industry, TV broadcasting of sports events, rock concerts, filming of publicity shots & video clips); as an exception, mention should be made of the rather large VTOL UAVs coming on the market in Japan for agricultural applications.

However, interest in using UAVs is growing within the scientific world, as is witnessed by the Australian/US Aerosonde meteorology programme, and the Swedish WITAS programme concerning the development of a fully autonomous VTOL UAV system with rational decision making capabilities for, amongst others, traffic surveillance tasks, NASA's Environmental Research Aircraft & Sensor Technology (ERAST) research programme using the Altus UAV, and the establishment of CIRPAS (Center for Interdisciplinary Remotely Piloted Aircraft Studies) in Monterey, CA, by the US Office of Naval Research, with the purpose to provide UAV flight services to support research. A special mention can be made of the study being undertaken by the Baltic states relative to the use of a high flying long endurance UAV, which would be used to relay command & control uplinks to, as well as imagery downlinks, from lower flying smaller UAVs deployed by the participating countries around the Baltic Sea for various purposes, such search & rescue (SAR), and maritime pollution control.

Telecommunications and pay-for-what-you-watch TV companies are investigating the use of very long endurance UAVs as «surrogate low altitude satellites» for relay purposes; this type of UAV application could find a market not only in industrialized nations, but could also help bring modern telecommunications to lesser developed countries. China has expressed keen interest in such systems.

PRINCIPAL UAV MANUFACTURERS

Figure V gives an overview of the world's principal current UAV manufacturers. Due to the limits imposed by what can legibly be put on a single page, this table does not mention manufacturers of lighter-than-air UAVs (which are mentioned separately), nor aerial targets and decoys; however some reference is made to the latter in this document.

Figure V indicates UAV manufacturers alphabetically by country, designating their UAV systems by name, and detailing the type of airframe (fixed or rotary wing, high speed small wing), UAV class (tactical or strategic), UAV category (micro, mini, close range, short range, medium range, low altitude deep penetration, medium range endurance, low altitude endurance, medium altitude long endurance, high altitude long endurance, offensive), and UAV application.

High speed small wing airframes are to be understood as cylindrical fuselages with stub-wings and in some cases canards or foreplanes, which are launched from zero-length launchers by means of RATO (CL289) or air-launched (Mirach 150).

UAV INDUSTRY

The principal UAV system manufacturers (current & potential) can be devided into two categories:

A- Major Defence Manufacturers

(UAVs are **NOT** core technology)

- Aérospatiale Matra, France ♦
- Alliant Techsystems, USA
- Bell Helicopter Textron, USA
- Boeing, USA
- British Aerospace, UK
- Dassault Aviation, France
- Dawoo Heavy Industries, South Korea
- DaimlerChrysler Aerospace (DASA), Germany
- ENICS, Russia
- Fuji Heavy Industries, Japan
- GEC-Marconi, UK (now BAe)
- Kawada Industries, Japan
- Kaman Aerospace, USA
- Kamov, Russia ♦
- Matra BAe Dynamics, France & UK
- Northrop Grumman, USA ♦
- Oerlikon-Contraves, Switzerland
- Raytheon, USA
- Saab, Sweden
- SAIC, USA
- Sikorsky Aircraft, USA
- Sokol, Russia
- Teledyne Ryan Aeronautical, USA ♦
- Thomson-CSF Detexis, France
- TRW, USA
- Tupolev, Russia ♦
- Turkish Aerospace Industries, Turkey ♦
- Yakovlev, Russia
- Yamaha Motor Company, Japan
- Yanmar, Japan

B- UAV System Manufacturers

(UAVs **ARE** core technology)

- AAI Corp., USA
- Aerosonde Robotic Aircraft, Australia
- AeroVironment, USA
- ATE, South Africa
- BAI Aerosystems, USA
- Bombardier-Canadair, Canada
- CAC Systèmes, France ♦
- Dornier (DASA), Germany
- EES, Turkey
- EMT, Germany
- General Atomics Aeronautical Systems, USA
- Insitu Group, USA
- Israeli Aircraft Industries, Israel
- Kentron, South Africa ♦
- Meteor, Italy ♦
- Mission Technologies, USA
- Pioneer UAV Inc., USA
- Sagem, France
- Techno-Sud Industries, France

Figure I **Overview Of Current UAV System Manufacturers (excluding aerial targets & decoys)**

COUNTRY	MANUFACTURER	SYSTEM	AIRFRAME		CLASS		CATEGORY	APPLICATION
Australia	Aerosonde Robotic Aircraft	Aerosonde	FW				LAE	Meteorology & research
	British Aerospace Australia	Nulka		VTOL	Tactical		Decoy	Decoy
Austria	Schiebel Elektron. Geräte	Camcopter		VTOL	Tactical		CR	RSTA, mine detection
Brazil	Gyron Sistemas Autonomos	Helix		VTOL	Tactical		CR	RSTA
Canada	Bombardier-Canadair	CL327 & 427		VTOL	Tactical		MR	RSTA, comms relay
Czech Republic	VTUL a PUL	Sojka III	FW		Tactical		SR	RS
France	Aérospatiale Matra	CL289	HSSW		Tactical		LADP	RS
		Hussard	FW		Tactical		CR	FOG RSTA
	Altec Industries	S-Mart	FW		Tactical		SR	RSTA
	CAC Systèmes	Fox AT & TX	FW		Tactical		SR	RSTA
		K100	FW		Tactical		LETH	Anti-vehicle & structure
	(in coop. w EDT & Dragonfly)	Heliot		VTOL	Tactical		SR	RSTA
	Envol Images	unnamed		VTOL	Tactical		MINI	Commercial
	Matra BAe Dynamics	Dragon	FW		Tactical		SR	EW
	Sagem	Crecerelle	FW		Tactical		SR	RSTA & EW
		Marula	FW		Tactical		LETH	RSTA & EW
		Sperwer	FW		Tactical		MR	RSTA
		Ugglan	FW		Tactical		MR	RSTA
	SurveyCopter	SurveyCopter		VTOL			MINI	Commercial
	Techno-Sud Industries	Vigilant 2000		VTOL	Tactical		CR	RS
		Vig.-Fuji 5000		VTOL	Tactical		MR	RSTA
		Vigiplane	FW		Tactical		CR	RS
	Thomson-CSF	Camcopter		VTOL	Tactical		CR	RSTA, mine detection
Germany	Dornier	CL289	HSSW		Tactical		LADP	RS
		Seamos		VTOL	Tactical		SR	RSTA, comms relay
	EMT	Luna	FW		Tactical		CR	RS
	STN Atlas Elektronik	KZO & Tucan	FW		Tactical		MR	RSTA
		Taifun	FW		Tactical		LETH	Anti-vehicle & anti-structure
		Mücke	FW		Tactical		MR	EW
		Mini-Tucan	FW		Tactical		CR	RSTA
Greece	3 Sigma	Nearchos	FW		Tactical		SR	RSTA
International Cooperation	- Matra BAe Dyn./France & STN Atlas Elektron./Germany	Brevel (KZO)	FW		Tactical		MR	RSTA
	- AAI/USA & IAI/Israel	Pioneer	FW		Tactical		SR	RSTA
	- TRW/USA & IAI/Israel	Hunter	FW		Tactical		MR	RSTA
	- ES&S/Austral. & Insitu/USA	Aerosonde	FW				EN	Meteorology & research
	- Eagle, Belgium & IAI, Israel	Hunter B	FW		tactical		MR	RSTA
	- Matra BAe Dyn. & IAI, Israel	Eagle Star	FW			Strategic	MALE	RSTA
India	ADE, Bengalore	Nishant	FW		Tactical		SR	RSTA
Israel	Israeli Aircraft Industries	Scout	FW		Tactical		SR	RSTA
		Searcher II	FW		Tactical		MRE	RSTA
		Harpy	FW		Tactical		LETH	Anti-radar
		Heron	FW			Strategic	HALE	RSTA
	Silver Arrow	Micro-V	FW		Tactical		SR	RS
		Sniper	FW		Tactical		MR	RSTA
		Hermes 450S	FW		Tactical		MRE	RSTA
		Hermes 1500	FW			Strategic	HALE	RSTA
Italy	Meteor (Alenia)	Mirach 20 & 26	FW		Tactical		SR	RSTA
		Mirach 100 & 150	HSSW		Tactical		LADP	RS
Japan	Fuji Heavy Industries	RPH2		VTOL	Tactical		MINI	Agriculture
	Kawada	RoboCopter 300		VTOL	Tactical		MINI	Agriculture
	Kubota Co.	KG200		VTOL	Tactical		MINI	Agriculture
	Yamaha Motor Co.	R50, R-Max		VTOL	Tactical		MINI	Agriculture
	Yanmar Agricult. Equipment	KG135II, YH300		VTOL	Tactical		MINI	Agriculture
South Africa	ATE	Vulture	FW		Tactical		SR	Artillery correct.
		Super Vulture	FW		Tactical		MRE	RSTA, EW
	Kentron	Seeker	FW		Tactical		MR	RSTA
		Lark	FW		Tactical		LETH	Anti-radar
South Korea	Daewoo	Bijo	FW		Tactical		MR	RSTA
		Arch 50		VTOL	Tactical		MINI	Agriculture
Sweden	Scandicraft Systems	Apid		VTOL	Tactical		SR	RSTA, EW
	Techment	RPG MK I, II, III		VTOL	Tactical		SR	RSTA
Switzerland	Oerlikon-Contraves	Ranger	FW		Tactical		MR	RSTA
Turkey	EES	Kirlangic	FW		Tactical		SR	RSTA
		Dogan	FW		Tactical		MR	RSTA
UK	Airspeed Airships	AS-100, 400, 600		L-t-A			MINI	Commercial
	Intora-Firebird	Firebird		VTOL	Tactical		SR	various
	Flight Refueling	Raven	FW		Tactical		SR	RSTA
	GEC-Marconi	Phoenix	FW		Tactical		SR	RSTA
	Meggitt Aerospace	Phantom	FW		Tactical		CR	RS
		Spectre	FW		Tactical		SR	RSTA
USA	AAI Corp	Shadow 200	FW		Tactical		SR/MR	RSTA
		Shadow 400	FW		Tactical		MR	RSTA
		Shadow 600	FW		Tactical		MRE	RSTA, comms relay
	AeroVironment	Pointer	FW		Tactical		CR	RS
	Alliant Techsystems	Outrider	FW		Tactical		MR	RSTA
	BAI Aerosystems	Exdrone/Dragon	FW		Tactical		SR	RS
		Javelin	FW		Tactical		CR	RS
	Bell Helicopter Textron	Eagle Eye		VTOL	Tactical		MR	RSTA, comms relay
	Boeing	Can. Rotor Wing		VTOL	Tactical		MR	RSTA
		Heliwing		VTOL	Tactical		MR	RSTA, comms relay
	Freewing Aerial Robotics	Scorpion		STOL	Tactical		MR	RSTA
	General Atomics	Altus	FW			Strategic	HALE	Research
		I. GNAT	FW			Strategic	MALE	RSTA
		Prowler II	FW		Tactical		MRE	RSTA
		Predator	FW			Strategic	MALE	RSTA
	In Situ Group	Laima	FW				LAE	Meteorology & research
	Lear Astronics	SkyEye	FW		Tactical		MR	RSTA
	Lockheed Martin/Boeing	Darkstar	FW			Strategic	HALE	RS
	Mission Technologies (Mi-Tex)	Backpack UAV	FW		Tactical			CR
	NASA/Scaled Composites	Raptor	FW			Strategic	HALE	Research/Offensive
	Northrop Grumman	Sea Ferret	FW		Tactical		MR	R, offensive
		BQM-74C Recce	HSSW		Tactical		MR	R
	Pioneer UAV Inc.	Pioneer	FW		Tactical		MR	RSTA
	SAIC	Vigilante		VTOL	Tactical		MR	RSTA, comms relay
	S-Tec	Sentry	FW		Tactical		SR	RS
	Teledyne Ryan Aeronautical	Global Hawk	FW			Strategic	HALE	S
		Scarab	HSSW		Tactical		MR	R
	United Technolog. Sikorsky	Cypher		VTOL	Tactical		SR	RSTA

EXPLANATION :

FW = Fixed Wing	CR = Close Range	SR = Short Range	MRE = Medium Range Endurance
VTOL = Vertical Take-Off and Landing	LAE = Low Alt. Endur.	MR = Medium Range	LETH = Offensive
MALE = Medium altitude long endurance	HALE = High altitude long endurance		RS = Recon/surveillance
HSSW = High speed small wing	RSTA = Reconnaissance, surveillance, target acq.		R = Reconnaissance
LADP = Low Altitude Deep Penetration	EW = Electronic warfare		S = Surveillance

- Silver Arrow, Israel
- S-Tec, USA
- Schiebel Elektronische Geräte, Austria
- STN Atlas Elektronik, Germany

It is of interest to note that a number of the aforementioned companies also produce unmanned aerial target vehicle systems (UATV)(see ♦). There are also manufacturers specializing in UATV systems (core technology), and which consequently master certain UAV-related technologies, such as:

- Advanced Electronic Systems, United Arab Emirates
- Bristol Aerospace, Canada
- Flight Refueling, UK (developed & produced the Raven UAV)
- Meggitt Aerospace, UK
- STN Atlas-3 Sigma, Greece
- Tracor, USA (Marconi North America)
- Tasuma (UK) Ltd, UK

FIXED WING UAVs

By far the largest number of current UAVs in all categories are fixed wing UAVs with a great variety of airframe configurations, including: high wing with twin booms & inverted V tail (Aerosonde-Aerosonde Robotic Aircraft, Australia & Shadow 200-AAI Corp., USA); high wing with twin booms and twin fin tail unit (Nishant-ADE, India; Pioneer-Pioneer UAV Inc., USA; Mirach 26-Meteor, Italy; Shadow 400 & 600-AAI Corp. USA), low wing with twin booms (Ranger-Oerlikon-Contraves, Switzerland), mid-mounted delta wing with twin outward-canted fins & rudders (Sperwer-Sagem, France), low-mounted delta wing without horizontal tail surfaces (Spectre-Meggitt, UK), low-wing monoplane without horizontal tail surfaces (Brevel/KZO-Eurodrone, France), shoulder-wing monoplane (Luna-EMT, Germany), mid-mounted wings with dorsal and ventral fins (Taifun-STN Atlas, Germany), pod-and-twin tailboom high wing monoplane (Hunter-TRW, USA & IAI, Israel); twin-wing monoplane with sweptback fin and rudder with T tailplane and ventral fin (Outrider-Alliant Techsystems, USA and Hellfox & Vixen-Mission Technologies, USA), shoulder-winged pod fuselage with single tailboom with inverted V tail (EyeView-IAI, Israel), high-winged monoplane with boom fuselage and T tail unit (Raven-Flight Refueling, UK & Fox MLCS-CAC Systèmes, France & Vulture-ATE, South Africa & XRAE-DERA, UK), mid-wing double delta with endplate fins (Lark-Kentron, South Africa), parasol monoplane with pylon-mounted wing with pod and boom fuselage and T tail (Pointer-AeroVironment, USA), semetrical delta wing with single fin and rudder (Exdrone & Dragon-BAI Aerosystems, USA), pod fuselage with inboard wing stubs & outboard freewings and articulated twin tailbooms (Scorpion-Freewing Aerial Robotics, USA), low-wing monoplane with inverted V tail (Altus, GNAT, I.GNAT, Prowler, Predator (General Atomics, USA), high-winged delta with twin tailbooms with vertical tail surfaces bridged by double T tailplane (Sentry-S-Tec, USA). Fixed wing UAVs can have pusher engines, puller engines or both.

There is a relative small number of twin-engined UAVs: Dogan, Firefly and Krilangic (EES, Turkey), Hunter-(TRW, USA & IAI, Israel), Micro V and Hermes 450 & 1500 (Silver Arrow, Israel), Theseus (Aurora Flight Sciences, USA).

VERTICAL TAKE-OFF & LANDING UAVs

There is a constantly growing number of VTOL UAV producers and development programmes. There are currently more than thirty five companies in forteen countries involved with the production and/or development of more than forty six different VTOL UAVs. The principal manufacturers include: Bell Helicopter Textron in the USA, Bombardier Services in Canada, Dornier in Germany, Schiebel Elektronische Geräte in Austria, Sikorsky Aircraft in the USA, and Techno-Sud Industries in France. The Swedish company Techment has developed the cost-effective RPG, which is a gyroplane UAV. But by far the majority of the VTOL UAVs currently produced in the world are Japanese (Fuji, Kawada, Kubota, Yamaha, Yanmar) and are used in Japan for agricultural purposes.

The following companies produce, and in some cases specialize, in VTOL UAVs, or have rotary wing UAVs in development:

Manufacturer	***VTOL Designation***
- Adv. Aerospace Techn., USA	Spinwing
- AeroCam, USA	23F & 60F
- BAeAustralia, Australia	Nulka
- Bell Helicopter Textron, USA	Eagle Eye
- Boeing, USA	Canard Rotor/Wing
- Bombardier-Services, Canada	CL327
- CAC Systèmes, France	Heliot
- Daewoo Heavy Ind., S.Korea	Arch 50
- Dornier, Germany	Seamos
- Dragonfly Pictures, USA	DP-4
- Frontier Systems, USA	A160 Hummingbird
- Fuji Heavy Industries, Japan	- RPH-1 & 2 - Fuji 5000
- Gyros Sistemas Autons, Brazil	Helix
- Intora-Firebird, UK	Firebird
- Kaman Aerospace, USA	K-Max
- Kamov, Russia	KA-37 & KA-137
- Kawada Industries, Japan	Robocopter300
- MovingCam, Belgium	FlyingCam
- Orion Aviation, USA	Seabat 706
- SAIC, USA	Vigilante
- Scandicraft Systems, Sweden	APID
- Schiebel Elektr. Geräte, Austria	Camcopter
- SurveyCopter, France	SurveyCopter
- Techno-Sud Industries, France	Vigilant 2000 Vigilant 5000
- Techment, Sweden	RPG (gyroplane)
- Yamaha Motor Comp., Japan	R50 & R-Max
- Yanmar, Japan	KG35 & 135 YH300

LIGHTER-THAN-AIR UAVs

There is a slowly growing number of development programs in the field of lighter-than-air UAVs. These UAVs potentially have a military, as well as a civilian market. It could well be that commercial applications of lighter-than-air UAVs will be an earlier reality than for fixed and rotary wing UAVs. A limited number is already being used for commercial and scientific applications. Lighter-than-air UAVs are being developed and produced (see ♣) by the following:

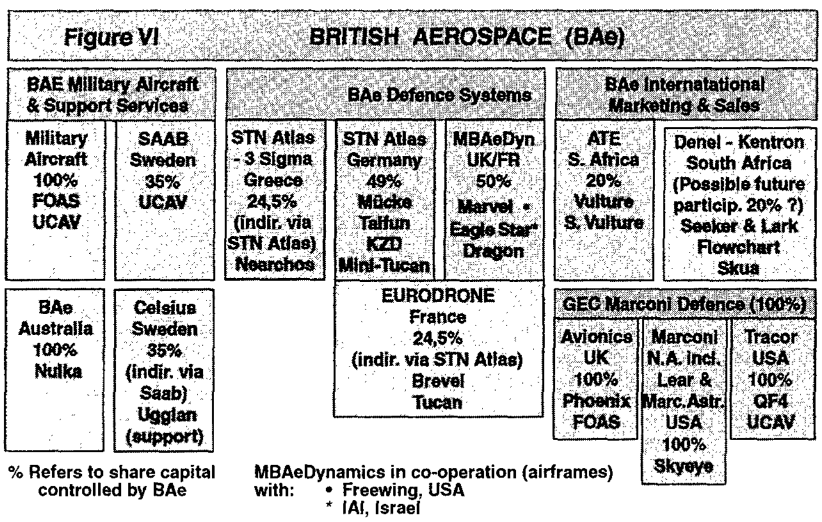
♣ - Advanced Hybrid Aircraft, USA	Hornet Hybrid RPB-35
♣ - Airspeed Airships, UK	AS-100 & 400 AS-600 & 800
- Automation Institute, Brazil	Aurora
- Aviation Industries China, China	FK-11 & 12

♣ - Bosch Aerospace, USA Sass-Lite
♣ - Envol Images, France El-4,5 & 10 & 15
- Pan Atlantic Aerospace, USA Leap
♣ - Promotional Ideas, UK PIG 1 & 2 & 3
- Shanghai Research Inst., China Shen Zhou 1 & 2
♣ - Skypia, Japan Mambow 4
- Skysat Systems Corp., USA
- TCom, USA 32M & 71M
- University of Stuttgart, Germany Lotte 3

INDUSTRY CONSOLIDATION

The following examples clearly illustrate the current drive towards consolidation in the UAV-related industry:

- BAe, UK and Matra, France have teamed to form Matra BAe Dynamics on a 50/50 basis.
- BAe, UK (minority) & Rheinmetal, Germany (majority)jointly own STN Atlas Elektronik, Germany.
- STN Atlas Elektronik has purchased 50% of 3 Sigma in Greece. The new company is called STN Atlas-3 Sigma, and is positioning itself as a serious competitor for the NAMFI Range (Crete) aerial target requirement and should be well positioned for the upcoming Greek divisional level UAV requirement.
- BAe, UK has taken a 20% stake in ATE, S. Africa. This participation was taken well ahead of the announcement by South Africa's Ministry of Defence of the award of contract to BAe for the supply of Hawk training aircraft.
- Kentron and Advanced Technology & Engineering (ATE), both of South Africa, are laying the groundwork for a combined company, probably together with Denel Aviation, that could be announced shortly. It is anticipated that in order to maintain the level of its stake in ATE, BAe will have to increase its stake in the new South African entity.



- BAe, UK has taken a 35% stake in Saab, Sweden.
- BAe, UK has purchased the defence activities of GEC Marconi,UK, system integrator of the Phoenix UAV, and which includes Tracor, USA (purchased by GEC in 1998), as well as Marconi Astronics Inc, USA.
- Saab and the government owned Celsius Group in Sweden have announced the take-over of the Celsius Group by Saab. The name of the new company is not yet knwon. As 35% of Saab's share captial is owned by BAe, this will further increase BAe's international industrial base.
- EES, Turkey has purchased EAS, Israel, a developer and producer of various twin-engined UAVs.
- FLIR Systems, USA (producer of gyro-stabilized EO/IR imaging payloads) has acquired Agema, Sweden (producer of IR imagers), Polytech, Sweden (development & design of gyrostablized camera platforms), BSS, UK (former FLIR Systems distributor), and Inframetrics, USA (producer of EO/IR imaging payloads).
- Lockheed Martin, USA has acquired McDonnell Douglas, USA.
- Lockheed Martin, USA is in the process of taking over Teledyne Ryan Aeronautical, USA.
- Matra Hautes Technologies, France has taken over Aérospatiale; the combined group is now called Aérospatiale Matra.
- Matra BAe Dynamics, France is rumoured to be in the process of negotiating a take-over of CAC Systèmes, France.
- Meggitt Aerospace, UK has acquired TTL, UK (UATV & engines), Cartwright, USA (Doppler radar-based missed distance indicators), Hayes Targets, USA (tow targets), Sabre, UK (acoustic missed distance indicators), and South West Aerospace, USA (tow winches).
- Sagem, France has taken over the French optronics manufacturer SFIM and the French electronics firm SAT.
- Schreiner Aviation Group has created Schreiner Target Services Canada, which has purchased the target division from Bristol Aerospace, Canada.
- Thomson-CSF has purchased Dassault Electronique; the combined group is now called Thomson-CSF Detexis.

Israel has two totally independant UAV manufactuers (Israeli Aircraft Industries and Silver Arrow) with substantial expertise. Where IAI already has a number of co-operation agreements with the Eagle Consortium, Belgium (Hunter-B), Matra BAe Dynamics, France & UK (Eagle Star), Oerlikon-Contraves, Switzerland (Ranger), TRW & S-Tec, USA (Sentry), Silver Arrow is not known to have a teaming arrangement with a foreign industrial partner. In view of the high cost of development, one wonders how long this situation can last. One must also wonder how long it will be viable for two distinct UAV manufacturers to coexist as separate entities in Israel, whose home market can obviously not warrant to keep both alive.

The recently announced amalgamation of Aérospatiale Matra, France and DaimlerChrysler Aerospace (DASA), Germany (EADS) is expected to make its presence felt in the UAV arena, but how and with what product is not really clear yet, unless the new group takes over an existing UAV manufacturer.

It can be concluded from the aforementioned that BAe has positioned itself as one of the major world players in the UAV arena, and definately the one with the widest international industrial base.

INDUSTRIAL COOPERATION

In order to be able to afford the investments required to bring a UAV system to maturity, or to overcome problems related to local content and in some cases offset commitments, industrial cooperation agreements (co-development and/or production) are starting to become more and more common on the international stage. To illustrate this point, the following examples are given:

Aerosonde	E.S. & S, Australia & Insitu Group, USA & Naval Research Laboratory, USA
Arch-50	Daewoo Heavy Industries, S. Korea & Kamov, Russia
Bijo	Daewoo Heavy Industries, S. Korea & AAI Corp., USA
Brevel	Eurodrone, a 50/50 joint venture between Matra BAe Dynamics (France & UK) and STN Atlas Elektronik, Germany
CL289	Bombardier-Canadair, Canada & Aérospatiale, France & DaimlerChrysler Aerospace, Germany
Crecerelle	Sagem, France & Meggitt Aerospace, UK
Darkstar	Lockheed Martin Skunk Works, USA & Boeing Military Aircraft Division, USA (continued development is stated to have been halted).
Eagle Eye	Bell Helicopter Textron, USA & Israeli Aircraft Industries, Israel & TRW, USA
Fox TX	CAC Systèmes, France & Thomson-CSF Detexis, France
Fuji 5000 Vigilant5000	Fuji Heavy Industries, Japan & Techno-Sud Industries, France
Global Hawk	Teledyne Ryan Aeronautical, USA & Lockheed Martin, USA & Raytheon Aircraft Co., USA
Heliot	Dragonfly, Italy & EDT, France & CAC Systèmes, France
Heron	Israeli Aircraft Industries, Israel & Matra BAe Dynamics, France & UK
Hunter	TRW Inc., USA & Israeli Aircraft Industries, Israel
Hunter B	Israeli Aircraft Industries, Israel Eagle Consortium, consisting of: - Sonaca, Belgium - Thomson-CSF Systems, Belgium - Thomson-CSF Electronics, Belgium - SAIT Systems, Belgium
Observer	Def. Evaluation Research Agency, UK & Cranfield Aerospace, UK & Tasuma (UK) Ltd, UK
Pioneer	Pioneer UAV Inc., a 50/50 joint venture between: AAI Corp., USA & Israeli Aircraft Industries, Israel
Ranger	Oerlikon-Contraves, Switzerland & Israeli Aircraft Industries, Israel & Swiss Aircraft Industries, Switzerland
RPG	Techment, Sweden & Army Intelligence School, Sweden
Shadow 600	AAI Corp., USA & Romanian company thru MoD
Siva	INTA, Spain & Ceselsa, Spain & DaimlerChrysler Aerospace, Germany
Spectre	Meggitt Aerospace, UK & Northrop Grumman, USA
UCAV/F-16	Lockheed Martin, USA & Tracor, USA
Vigilant5000	See Fuji 5000
Vigilante	SAIC, USA & Kawada, Japan

MARKETING ARRANGEMENTS

Teaming arrangements relative to the marketing of UAV systems in specific countries are becoming rather common, as is witnessed by the following examples:

Backpack	Mission Technologies, USA with Dornier (DASA), Germany - for marketing in selected countries.
Camcopter	Schiebel Elektronische Geräte, Austria with: Thomson-CSF Detexis Missiles - for marketing in France
Dragonfly	Dragonfly Sar, Italy, through their French distributor EDT, with: CAC Systèmes, France - for fitting the aircraft with an autopilot and marketing in selected countries.
Exdrone	BAI Aerosystems, USA with: Raytheon, USA - for competing for the US UAV target requirement.
Scorpion	Freewing Aerial Robotics, USA with: Northrop Grumman, USA - for the Tactical UAV competition in the USA with: Yamada International, Japan - for marketing in Japan
Marvel	Freewing Aerial Robotics, USA with: Matra BAe Dynamics, France - for marketing in France
Heron (Eagle Star)	Israeli Aircraft Industries, Israel with: Matra BAe Dynamics, France - for marketing in France & UK
Hunter B	Israeli Aircraft Industries, Israel with: the Eagle Consortium, Belgium - Sonaca, Belgium - Thomson-CSF Systems, Belgium - Thomson-CSF Electronics, Belgium - SAIT Systems, Belgium for marketing and production in Belgium
Pointer	Aerovironmet, USA with: CAC Systèmes, France - for marketing in Europe
Predator	General Atomics Aeronautical, USA with: Sagem, France - for marketing & logistical support in France with: Meteor, Italy - for marketing & logistical support in Italy with GEC-Marconi, UK - for marketing and logistical support in UK
Ranger	Oerlikon-Contraves, Switzerland with IAI, Israel - for marketing in Finland
Sentry	S-Tec, USA with TRW, USA and IAI, Israel - for marketing in the USA relative to the Tactical UAV programme
Skua (UATV)	Kentron, South Africa with Sagem, France - for marketing and logistical support in France
Vigilant	The airframe produced by Fuji Heavy Industries, Japan (Fuji 5000) and droned

by Techno-Sud Industries, France (TSI), is being marketed by TSI as Vigilant 5000 in Europe, Africa, Middle East and South America.

Vulture ATE, South Africa with BAe, UK - for marketing in selected countries.

CURRENT & UPCOMING UAV USERS

Figure VII gives an overview of the UAV systems in service, on order, or programmed in a sampling of countries around the world.

INTRODUCTION OF UAVs

The introduction of UAVs into the Armed Forces is a gradual process that is proceeding at different levels in different countries. Most of the industrialized world's military have firstly opted for tactical UAVs on a divisional level and are currently envisaging the introduction of strategic UAVs and/or regimental level tactical UAVs. The introduction of platoon level micro UAVs will start to follow in probably approximately five years (2005).

It should be mentioned that what is considered a regimental/brigade level system in one country, may be considered a divisional level system in another.

TACTICAL UAVs - Divisional Level

The first UAV wave to hit the world's defence forces principally concerned divisional level tactical systems. Such systems have been or are now in service, on order, are or have been under lease, or with Algeria, Australia, Belgium, Bulgaria, Czech Republic, Denmark, Egypt, Finland, France, Germany, India, Israel, Italy, Morroco, Netherlands, Romania, Russia, Singapore, South Africa, South Korea, Sri Lanka, Sweden, Switzerland, Thailand, Turkey, UAE, UK, USA. In nearly of of the aforementioned cases, the UAV systems are used for reconnaissance and surveillance, and in some cases also for target acquisition purposes.

Upcoming contracts or requests for proposals for this category of system are anticipated in the near, or not too distant future, in Australia, Canada, Croatia, Greece, Kuwait, New Zealand, Saudi Arabia, Turkey, U.A.E., UK, USA.

The leading manufacturers in the Medium Range and Medium Range Endurance categories are: AAI Corp/USA, GEC-Marconi/UK, General Atomics/USA, IAI/Israel, Kentron/South Africa, Meteor/Italy, Oerlikon-Contraves/Switzerland, Pioneer Inc/USA, Sagem/France, Silver Arrow/Israel, STN Atlas Elektronik/Germany.

MALE & HALE UAVs - Corps Level

The second, but much smaller wave, that is now starting to form concerns the high value tactical MALE (medium altitudfe long endurance) and strategic HALE (high altitude long endurance) UAVs; such systems have been developed by IAI/Israel, Silver Arrow/Israel, General Atomics/USA, Lockheed & Boeing/USA, Teledyne Ryan/USA. Only the USA military establishment has actually funded the development of this type of UAV systems (Darkstar, Global Hawk, Predator). Firm interest in these types of systems is, for the moment, principally restricted to the richer and more developed countries (Australia, France, Germany, Israel, Italy, Japan, Netherlands, Spain, Sweden, Turkey, UK, USA), but it should be noted that China, Iran, ROC-Taiwan are

Client Country	System in Service	Manufacturer (Prime Contractor)	On Order Or Programmed
Australia	Nulka	BAe Australia, Australia Teledyne Aeron., USA	Global Hawk ?
Austria		Ongoing RFP	Tactical UAV
Algeria		Kentron, South Africa	Seeker
Bahrain		BAI Aerosystems,USA	Dragon
Belgium	Epervier → ♦	MBLE Déf., Belgium IAI, Israel + Eagle, Belg.	Hunter B
Bulgaria		Techno-Sud,France	Vigilant
Canada		RFP delayed	Tactical UAV
Chili		Ongoing competition	Tactical UAV
Czech Rep.	Sojka III	VTUT à PVO,Czech Rep.	
Denmark		Sagem, France	Sperwer
Egypt	Scarab ♦ SkyEye ♦	Teledyne Ryan, USA Lear Astronics, USA Ongoing competition Ongoing rqmt (FMS)	Tactical EW UAV VTOL UAV
Finland		Oerlikon-Contraves, CH	Ranger
France	CL289 ⇓ Crecerelle Vigilant ♣ Hunter ♣	Aérospatiale/Dornier Cac Systèmes, France Sagem, France Techno-Sud, France TRW/USA & IAI/Israel	Sensor upgrade Fox MLCS Heliot EW Crecerelle
Germany	KZO (Brevel) LUNA CL289 ⇓	Eurodrone (STN Atlas) STN Atlas, Germany EMT, Germany Dornier/Aérospatiale	(KZD) Brevel Taifun & Mücke LUNA Sensor upgrade
Greece		Upcoming RFP	Tactical UAV
India	Searcher	ADE & Taneja Aerosp. Bangalore, India IAI, Israel	Nishant Searcher
Israel	Scout & Harpy Searcher Hermes 450S	IAI-Malat, Israel IAI-Malat, Israel Silver Arrow, Israel	
Italy	Mirach 20 & 26 Mirach 100	Meteor, Italy Meteor, Italy General Atomics	Mirach 150 Predator
Morroco	SkyEye ♦	Lear Astronics, USA	
Netherlands		Sagem, France EMT, Germany	Sperwer LUNA
Romania	Shadow 600 Vigilant	AAI Corp., USA Techno-Sud, France	Shadow 600 ?
Russia	Shmel-1	Yakovlev, Russia	
Singapore	Scout ⇓ Searcher II	IAI, Israel Upcoming competition	Searcher II Tactical UAV
South Africa	Seeker	Kentron, South Africa ATE, South Africa	Vulture
South Korea	Searcher Harpy	AAI Corp, USA Daewoo, South Korea IAI, Israel IAI, Israel	Shadow 400 Bijo
Sri Lanka	Scout ♦ ⇓	IAI, Israel | Ongoing RFP	Tactical UAV
Sweden	RPG MK III ♣ Ugglan	Techment, Sweden Sagem, France Mission Techno., USA	Mini-Vanguard ♣
Switzerland	Ranger	Oerlikon, Switzerland	Ranger
Thailand	SkyEye ♦ Searcher II ♣	Lear Astronics, USA IAI, Israel	
Turkey	GNAT 750	General Atomics, USA Ongoing competition	Tact & Strat. UAV
U.A.E.	Seeker	Kentron, South Africa Upcoming RFP	Tactical UAV
UK	Phoenix	GEC Marconi Avionics 2 Upcoming RFPs	Sender& Spectator
USA	Camcopter ♣ Exdrone/Dragon Global Hawk Hunter ♣ I.GNAT Outrider ♣ Pioneer Pointer Predator Sentry	Schiebel, Austria BAI Aerosystems Teledyne Aeronautical TRW, US & IAI, Israel General Atomics Alliant Techsystems Pioneer UAV Inc. AeroVironment General Atomics S-Tec Ongoing competition Ongoing competition	Camcopter Global Hawk Predator Tactical UAV VTOL naval UAV

Figure VII - UAV Systems : Deployed, On Order or Programmed

Explanation : → = end of service life ⇓ = nolonger in prod.
♦ = nolonger fully operational ♣ = test/eval. system

Figure VIII — **Review of the Currently Existing MALE & HALE UAVs**

Characteristics	HERON (Eagle) MALE	HERMES 1500 MALE	I.GNAT MALE	PREDATOR MALE	GLOBAL HAWK HALE	DARKSTAR HALE (cancelled)
Altitude :						
Max m	9150	9145	> 7620	7925	19800	15200
Operating m	8075	8000	7620	4600	15-19200	15200
Endurance						
Max. hours	50	> 40	40	> 40	38	12
Action radius km	926	200 km	700	926	5556	>926
Speed						
Max. km/h	....	315	230	210	>639	556
Cruise km/h	231	241	140	125	639	556
Loiter km/h	130 - 148	148	120	115	630	241
Climb rate						
Max. m/min	198	457	?	244	1036	610
Deployment	?	?	Multi C-130 sorties GS: Multi C-141,	Multi C-130 sorties or C-5 sorties	AV: Self-deployable	Multi C-141, C-17
Propulsion	1 x 4 cyl., 4-stroke pusher propeller	2 x 4 cyl., 4-stroke 2 x pusher prop.	1 x 4 cyl., 4-stroke pusher propeller	1 x 4-stroke pusher propeller	1 x turbofan	1 x turbofan
- Producer	Rotax	Rotax	Rotax	Rotax	Allison	Williams
- Model	914	914	912 or 914	912 or 914	AE3007H	FJ44-1A
- Rating	75.8 kw - 105 HP	75.8 kw - 105 HP	63.4 kw - 85 HP; or 75.8 kw - 105 HP	63.4 kw - 85 HP; or 75.8 kw - 105 HP	32 kN	8.45 kN
- Fuel type	AVGAS (100 oct.)	AVGAS (100 oct.)	AVGAS (100 oct.)	AVGAS (100 oct.)	Heavy fuel (JP-8)	Heavy fuel (JP-8)
- Cap. liters	720	?	309	409	8176	1575
Weight :						
Empty kg	600	?	385	544	4055	1978
Fuel kg		?	227	300	6668	1470
Payload kg		400	91	204	889	454
Fuel + payl. kg	500					
Max. TO kg	1100	1500	703	1134	11612	3901
Dimensions :						
Wingspan m	16.60	10.00	12.80	14.80	35.40	21.00
Length m	8.50	8.60	5.75	8.10	13.50	4.60
Height m	2.30	?		2.20	4.60	1.50
Avionics :						
Transponder	Mode IIIC IFF ?	Mode IIIC IFF ?	Mode IIIC IFF	Mode IIIC IFF	Mode I/II/IIIC/IV IFF	Mode IIIC IFF
Navigation	GPS & INS	GPS & INS	GPS (INS option)	GPS & INS	GPS & INS	GPS & INS
Launch/Recovery	Runway	Runway	Runway	Runway (760 m)	Runway (1524 m)	Runway (<1219 m)
Comm. & Control	Remote control & preprogrammed	Remote control & preprogrammed	Remote control & preprogrammed	R.Contr/Prepgmd/ autonomous	Preprogrammed/ autonomous	Preprogrammed/ autonomous
Sensors	EO/IR, maritime radar (Elta)	EO/IR	EO/IR, SAR	EO, IR, SAR	EO, IR, SAR	EO or SAR
Data links :						
Type Uplink	C-band LOS	C-band LOS ?	C-band LOS	G-band LOS (Ku-band growth)	UHF LOS & Satcom X-band	UHF LOS & Satcom X-band
Downlink	C-band LOS	C-band LOS ?		Ku-band Satcom J-band Satcom	CDL LOS & Ku-band Satcom	CDL LOS & Ku-band Satcom
Bandwidth	20 MHz	?	20 MHz ?	C-band : 20 MHz Ku-band Satcom : RL/CL 5/9 MHz	UHF LOS/Satcom : 25/25 kHz X-CDL LOS: RL/CL: 137/64 MHz Ku-Satcom: RL/CL: 3-69/0.26 MHz	UHF LOS/Satcom : 9.6/25 kHz DAMA X-CDL LOS: RL/CL: 137/64 MHz Ku-Satcom: RL/CL: 26/(N/A)MHz
Data rate : - analog Hz - digital bps	20 MHz	?	20 MHz ?	C-band : 20 MHz Ku-band : RL : 1.544 Mbps CL : 64 kbps	UHF : 9.6/9.6 kbps X-CDL : RL : 137 Mbps CL : 200 kbps Ku-Satcom : RL : 1.5-48 Mbps CL : 200 kbps	UHF : 4.8/1.2 & 2.4 X-CDL : RL : 137 Mbps CL : 200 kbps Ku-Satcom : RL : 1.54 Mbps CL : (N/A)
C2 Links	Through data link	?	Through data links	Through data links	Through data links	Through UHF LOS, UHF Satcom, or CDL LOS
Prime or Key Contractors	Israel Aircraft Ind. (& Matra BAe Dyn.)	Silver Arrow	General Atomics	General Atomics Aeronautical Syst.	Teledyne Ryan Aero	- Lockheed Martin - Boeing

also starting to express interest in this type of UAVs.

The first prototype of Teledyne Ryan's Global Hawk HALE UAV was rolled out in February 1997. Its first flight took place in February 1998. The second prototype flew for the first time in November 1998; it was lost in crash in March 1999. This unfortunate accident has apparently not hampered the USAF's ardour, nor brought the programme's financing into danger. Global Hawk is the only UAV in its category currently flying, and it is doubtful if a similar aircraft will be rolled out in the near future by another manufacturer. Nevertheless, it should be mentioned that several development studies for HALE UAVs are currently ongoing (Aerospatiale/France, Dassault Aviation/France, Saab/Sweden).

General Atomics Aeronautical System's Predator MALE UAV is an improved and larger version of the initial GNAT, and an eviable success story. General Atomics was initially awarded a US$ 31,7 million, 30 month Advanced Concept Technology Demonstration contract (10 A/Cs & 3 GCSs) by the US Navy in January 1994. Since then, over 55 aerial vehicles have been ordered by the USAF and CIRPAS (35 A/C delivered), and Predators have been extensively deployed over Bosnia, and more recently over Kosovo, logging in total more than 13.000 flight hours.

The Italian Ministry of Defence is has programmed the purchase of a Predator system (6 aircraft, 1 or 2 GCSs) for the beginning of 2000. The Italian Air Force will operate this system. The possible second ground control station would be used onboard an Italian Navy ship. One of the system's initial pressing tasks will be the surveillance of the Adriatic Sea for clandestine immigrant and smuggling control.

The United Kingdom MoD is looking at the possibility of leasing a Predator system for approximately one year in order to gain operational experience within a short

timeframe, prior to formulating operational requirements.

France is currently in the process of evaluating several MALE contenders (Eagle Star-Matra BAe Dynamics & IAI/Israel, Predator-Sagem/France & General Atomics/ USA). In this context, it is of interest to mention that the French MoD-DGA has decided to use a highly sophisticated software simulation tool developed by Dassault in cooperation with ONERA (French aeronautical research organization), to compare the system software of the various proposed UAV systems. Aérospatiale Matra and Dassault Aviation are both active within in-house development work in the field of HALE UAVs.

Germany has initiated a study contract relative to MALE UAVs, and is rumoured to be reconsidering the Grob airframe as the basis of an indigenous MALE UAV.

Turkey, whose military froces already operate the GNAT UAV system (General Atomics Aeronautical, USA), issued an extremely ambitious request for proposal in 1998 concerning three different types of UAVs, with a reported budget of approximately US $ 500 million budget. The Turkish Ministry of Defence received proposals from Catic/China, General Atomics/USA, and IAI/ Israel. This requirement has been downscaled (only two types of UAV systems now constitute the requirement) and the financial implications of the recent earthquakes have further sapped the Ministry of Defence's budget, and this has caused an even further decrease of the requirement.

The Australian Ministry of Defence (Royal Australian Air Force) has expressed very keen interest in the Global Hawk. One of the principal purposes Australia would like to put this system to, is the control of the waters to the north east of the continent for illegal immigrant and regional surveillance. The interest is so keen that under an A$ 30 million agreement announced ni March 1999, Australia's Defence Science and Technology Organization is to cooperate with the USAF and Teledyne to develop a maritime surveillance version of Global Hawk's current synthetic aperture radar and evaluate the system's suitability to meet the RAAF's requirement.

An overview of the current MALE and HALE UAVs can be found in Figure VIII. For reference purposes, this table also includes the now cancelled DarkStar HALE. The DarkStar HALE system was developed under a 31 month ACTD contract awarded by ARPA to Lockheed Martin and Boeing in June 1994. The first prototype was rolled out in June 1995 and flew for the first time in March 1996, and subsequently crashed in April 1996. The second prototype flew several times, before the programme was terminated by the USAF, reportedly after having come to the decision that its military utility was insufficient to justify completion. However, the idea should not be excluded that the DarkStar development will continue as a "black" programme.

TACTICAL UAVS - Regimental/Brigade Level

A third and potentially larger UAV wave, which is currently starting to form, concerns brigade/regimental level fixed and rotary wing tactical UAV systems. The applications of these systems include: over-the-hill reconnaissance, aerial mine detection, urban warfare, NBC monitoring, communications relay. Interest for this category of systems has been expressed by Australia, Austria, Bahrain, Croatia, France, Germany, Singapore, Sweden, UK, USA). The applications of these systems include: over-the-hill reconnaissance, aerial mine detection, urban warfare, NBC monitoring, communications relay.

The leading manufactuers in this category are: AeroVironment/USA, BAI Aerosystems/USA, CAC Systèmes/France, EMT/Germany, Mission Technologies/USA, Scandicraft/Sweden, Schiebel Elektronische Geräte/Austria, Sikorsky Aircraft/USA, Silver Arrow/Israel, S-TEC/USA, Silver Arrow/Israel, STN Atlas Elektronik/Germany, Techment/Sweden, and Techno-Sud Industries/France.

These systems will probably be the most accessible, the easiest to exploit and the simplest to integrate into the military structures of non-industrustrialized and lesser sophisticated countries. In this category of UAV systems, Sweden has actively explored the potential of a rotary wing aircraft, namely the RPG III, a gyroplane-based UAV with vertical take-off and very short landing characterics.

The Swedish Coastal Artillery is rumoured to have awarded a sole source contract to Mi-Tex, USA for the supply of a single Mini-Vanguard UAV system for experimental purposes; this UAV incorporates Ti-Tex's well-known twin-wing principal, that was also used on Alliant TechSystems' Outrider UAV. Delivery is said to be scheduled for December 1999.

The Royal Netherlands Army has recently purchased a Luna UAV system from EMT, Germany for experimental purposes.

The Bahrain Defence Forces have just taken delivery of Dragon UAVs from BAI Aerosystems, USA.

Requests for Proposal and contracts for such systems may be expected in Germany (AAMIS programme), the Netherlands (Luna, as an extension of the joint German-Dutch Fennec programme; Luna is part of the German Fennec reconnaissance system), Sri Lanka (to replace the IAI Scouts, that have now all crashed), UK (Sender programme).

These relative small and highly mobile UAV systems are rather price-sensitive, but also seem to offer, in time, the largest production volume and sales potential. The sales of these systems will probably face less obstacles than larger tactical UAV systems to find new customers, as they will be substantially cheaper, easier to deploy and operate, incorporate less sensitive and more commercial-of-the-shelf components.

VTOL UAVs

While most of the aforementioned UAVs concern fixed wing aircraft, it is to be noted that distinct interest is starting to be shown in UAVs for urban reconnaissance surveillance, EW and psy ops roles during conditions of civilian unrest, strife and war, littoral warfare, land and sea mine detection, naval communication relay, naval over-the-horizon targeting and landing naval supplies, and that the aircraft being considered for these roles all seem to be either VTOL or S/TOL UAVs.

Operational scenarios for VTOL UAVs have already been indentified in a number of countries (e.g. Egypt, France, Germany, Japan, Sweden, USA) and have resulted in the definition of operational requirements.

A number of other countries, including Saudi Arabia and South Africa, are in the process of formulating operational requirements. Recently, Egypt issued a RFP for VTOL UAVs (which were specified as having to be of American origin as they were to be purchased with FMS credits). The US Marine Corps has just awarded a development contract to Sikorsky for the development of the Cypher II, a winged version of the circular shrouded

rotor UAV, which has a pair of four-blade, coaxial, bearingless rotors. This new UAV is to be called Dragon Warrior and is aimed at an urban warfare role.

Figure IX VTOL Categories	Payload Cap. in kg	Mission Radius in km	Endurance in hours
1- Land-launched	10-25	in-sight	1-2
2- Land- & Ship-Launched	30	25-30	3 at 25-30 km
3- Land-launched	50	50	1-3
4- Ship-launched	50	100	2 at 100 km
5- Land- & Ship-Launched	>50	>100	5 & more

Taking into account payload capacity, operational range and flight endurance, VTOL UAVs can be categorized as indicated in Figure IX.

The principal problem in the development of VTOL UAVs is to make them fully autonomous, including out-of-sight precision hovering and automatic take-off & landing, including from & on naval ships. The 1998 US Navy VTOL demonstration has shown the current level of technology maturity in these areas.

As things stand at the moment in relation to ATM issues, VTOL UAVs may have an easier entry into a commercial UAV market (captive & potential) than fixed wing UAVs, which probably explains the fact that considerable R&D efforts are being deployed in this field all over the world. Japan is the forerunner; today more than 2000 VTOL UAVs are being commercially operated there by specialized and certified operators.

OFFENSIVE UAVs

Lethal UAVs can be considered as a cost-effective version of a cruise missile. Strictly speaking, they do not, in their operational configuration, fit the definition of UAVs given earlier, as they are expendable and not reusable. However, they can also be seen as an extrapollation of UAVs, using detection & identification sensors and mission software specific to their mission.

Seen from a volume, some of the largest UAV contracts recently concluded, concerned offensive UAVs (STN Altas Elektronik's anti-vehicle & anti-structure "Taifun" in Germany & IAI's anti-radar "Harpy" in South Korea).

The fully programmable and autonomous Taifun is intended to attack selected tanks, artillery, radar posts, command structures and logistical assets well behind enemy lines. Taifun will be equipped with a high-resolution K-band millimeter wave radar (MMW) seeker with a moving target indication (MTI) and Doppler beam capability, and a shaped charge warhead. It is to be launched in swarms from truck-mounted launching canisters and then continues on its preprogrammed flight mission to the search zone where it can loiter at 120 km/h for 4 hours searching for its preprogrammed targets. Once the required target has been detected, recognized and identified, Taifun can either operate as a fire-and-forget weapon, or be directed by operator in its final kill phase. Full-scale development of the Taifun was launched in late 1997 and the first system is programmed to be delivered for operational and qualification tests in 2003.

The programmable anti-radiation Harpy offensive UAV is based on the DAR, originally developed by Dornier,Germany, and is equipped with a high-explosive warhead. It is launched by means of a booster rocket from a truck-mounted container. It has been reported that during NATO's recent offensive against Serbia, serious consideration was given by the US to the deployment of Harpy offensive UAVs.

Cutlass is a variant of Harpy, developed by IAI in cooperation with Raytheon E-Systems, USA for the suprression of enemy air defence (SEAD) role; Cutlass uses the seeker head of the AIM-9 Sidewinder anti-aircraft missile (Raytheon) and the automatic target recognition and classification algorithms also developed by Raytheon.

CAC Systèmes, France is developing the K100 anti-structure and vehicle lethal UAV, which is said to be equipped with a video homing device and compatible with several existing warheads, including that of the Matra Apilas anti-tank missile.

Kentron, South Africa, under contract to the South African Air Force, has developed the autonomous anti-radiation Lark for SEAD and an anti-radar roles; however, due to governmental financial restrictions the Lark has not entered into service.

Sagem has perfected the anti-radiation Marula, which it acquired through their take-over of Aéronautiques & Systèmes, France (AES). It is of interest to remark that the origin of the Marula can also be found in South Africa, where initial development had taken place prior to the project being purchased by AES. Both developments were auto-financed by the involved companies.

ARMED UAVs

The feasibility of equipping UAVs with laser designators has already been proven. There are now also ongoing studies in the USA related to the fitting of larger UAVs with existing missiles (e.g. Hellfire) to conduct missions such as SEAD, urban warfare, precision strikes against targets of opportunity discovered during surveillance missions and the support of special forces.

The boost phase intercept of ballistic missiles using anti-missile missiles launched from a high circling UAV is also seriously being considered (Israel, USA).

Initially, Armed UAVs will be fitted with existing, and possibly slightly modified, weapons and/or weapon delivery systems. As the concept is refined, and their operational advantages are proven, it stands to reason that specific weapon systems will be developed for these aircraft.The UAVs that can be considered for such a role are very much in function of the payload capacity required to carry the relative weapon system and the fuel necessary to bring the UAV to the theatre of operations. It can be envisaged that Armed UAVs could be land-, ship- and air-launched. It can also be envisaged that droned (formerly piloted) aircraft could be used for this role.

It stands to reason, that Armed UAVs will be a necessary stepping stone towards the future uninhabited combat aircraft (UCAV).

LIGHTER-THAN-AIR UAVs

It is of interest to note that lighter-than-air UAVs, in other words droned airships, are starting to be spoken about. In fact, these systems offer substantial advantages for a certain number of missions where speed and vulnerability are not of extreme importance. The scenarios that could be envisaged are not necessarily military. Extremely dull missions, and which can be totally automated, such as advertising, forest fire control, forestry inspection, crop inspection, power line inspection, cargo transport, searching for tuna concentrations, meteorological purposes, ice & snow cap measurement, communication relay platform, mapping, filming certain sports events (offshore powerboat & sailing races), as well as a number of environmental research applications.

Currently, lighter-than-air UAVs are being used by broadcast TV teams for sportscasting and filming rock concerts (principally indoors).

Other missions that these craft could be used for include fishery control, economic interest zone monitoring, smuggling control, ship traffic monitoring.

Companies involved with the development of this type of UAV include :

- Advanced Hybrid Aircraft Inc., USA
- Aviation Industries of China, China
- Envol Images, France
- Pan Atlantic Aerospace, Canada
- Promotional Ideas Group, UK
- Shanghai Aircraft Research Inst., China
- Skypia Company Ltd, Japan
- Skysat Systems Corp., Canada
- University of Stuttgart, Germany

MICRO UAVs

The distant buzz of Micro UAVs is starting to be picked up. Interest in these systems has been recognized in France, Germany, Greece, Italy, Israel, Sweden, UK and USA, but to field this type of UAV substantial technological hurdles still have to be overcome.

The basic idea behind Micro UAVs is to increase situational awareness down to platoon level. They are envisaged to carry out missions in two types of environment: - urban areas;
- open terrain.

In urban areas Micro UAVs will fulfill day and night reconnaissance and surveillance roles, which will possibly also include the requirement to inspect the inside of buildings from the outside, or flying into them. This will require relatively slow flying and highly manoeuvrable aerial vehicles with low acoustic signatures, which will have to be equipped with some form of obstacle detection and collision avoidance system.Line-of-sight communications in this application will be pratically impossible, hence a new approaches must be investigated.

In open terrain Micro UAVs are expected to not only fulfill stand-off day and night reconnaissance and surveillance roles, but also roles such as unattended static surface sensor (e.g. EO, IR, acoustic, vibration), bacterological and chemical agent detection, communications relay, radar and communications jammer.

From the aforementioned it can be concluded that military operations in urban terrain (MOUT) will favour some form of VTOL UAV, and that military operations in open terrain will favour fixed wing UAVs. In both cases Micro UAVs will have to incorporate a high degree on onboard intelligence, be easily carriable and deployable by a soldier by means of a compact and robust ground control station and launch system.

The classic laws of aerodynamics and aircraft design to not apply to Micros, as their small size and low weight make them more akin to flying insects and birds than aircraft. In some cases, the approach being taken by designers is resulting in aerial vehicles, which ressemble flying insects, bats or birds and use trailing antennae as stabilizers.

Entomopters (electromechanical insects) and ornithopters (electromechanical birds) are being researched as possible solutions. Georgia Tech Research Institute is developing, in collaboration with the University of Cambridge, UK and ETS Labs, an entomopter using a propulsion unit based on a reciprocating chemical muscle, which converts chemical energy into motion by means of a non-combustive chemical reaction.The California Insitute of Technology is developing, in collaboration with AeroVironment, an ornithopter designated Microbat, which creates flight movement by flapping its wings, which are propulsed by a micro-electromechanical system.

In all cases innovation is required in many fields, such as micro power supply, micro propulsion, micro imaging sensors, micro altimeters, low power micro datalinks, low power micro electronics, and low power micro GPS. One can envision the downlinked imagery being displayed not only on the miniature screen of an individual soldior's handheld control station station, but alternatively also on the head-up display integrated into his helmet.

At this point in time, only the US DoD is making sizeable amounts of money available for research & development and studies relating to the future warfighter's individual UAV. The US Defence Advanced Research Projects Agency (DARPA), and the US Naval Research Laboratory (NRL) with funding from the US Office of Naval Research, have both initiated micro aerial vehicle programmes. DARPA's programme is a US $ 35 million, 4-year effort, that began in 1997 with the award of nine innovative research contracts (US $ 100.00 each) for the development of operating concepts and to demonstrate flight-enabling technologies. In 1998 four of the contracts progessed into Phase 2:

- Sanders, teamed with Lockheed Martin Skunk Works and General Electric Corporate R&D center) received the first US $ 690.000 of a US $ 10 million, 42 month contract for the development of the fixed-wing MicroStar micro. This µUAV is expected to weigh 85 gram and have a 15 gram EO payload and is controlled, by means of way points, by means of a laptop computer, a PCMCIA card and a 1 m wide folding umbrella dish.
- Lutronix Corp. received a US $ 200.000 study contract for its 4 inch rotary wing micro UAV, which is destined for urban reconnaissance.
- AeroVironment received a US $ 750.000 contract to develop micro UAV concepts for use in relatively open terrain, urban areas and jungle. AeroVironment has focussed on a non-hovering disc aircraft with a diameter of 15,24 cm weighing 50 gram distributed as follows :

Lithium battery	26 gram
Engine	7 g
Gearbox	1 g
Propeller	2 g
Airframe	4 g
Control actuators	1 g
Receiver & CPU	1 g
Downlink TX	3 g
B/W video camera	2 g
Interface electronics	1 g
Roll rate gyro	1 g
Magnetic compass	1 g

- Aerodyne Corp. received a US $ 750.000 contract to develop the Hyperav hovering disc micro UAV; it is expected to weigh up to 300 gram and will probably be powered by liquid fuel.

In all cases the aerial vehicles can be either hand-, munitions- or platform-launched, must be capable of transmitting near-real-time imagery, but must not exceed 15,24 cm (6 inches) in any dimension, be able to fly up to six miles at 64 to 80 km/h (40 to 50 m/h) and have an endurance of 20 min to 2 hours.

The following manufacturers also had technology demonstrations carried over into Phase 2 :

- M-Dot Inc. received a US $ 750.000 contract to continue development of a 1.4 lbf.-thrust gas turbine (dim. : length 7,62 cm, ø 4,318 cm), which was intended to be used on the Hyperav (Aerodyne, USA).
- IGR Enterprises Inc. received a US $ 750.000 contract to demonstrate a solid oxide fuel cell for micro UAVs, which is to supply enough energy to fly a 50 g micro UAV for several hours, while powering its payload. This fuel cell is to be flown on AeroVironment's micro.

Figure X	US Micro UAV Design Parameters	
Airframe types	- Rotary Wing - Fixed wing - Hovering disc - Insect wing - Ornithopter	
Contracting Authority	DARPA	Naval Research Lab
Size (max)	6 x 6 x 6 inches	wingspan: 6 - 8 inches
Weight (empty)		50 - 100 gr
Payload cap.	not defined	15 gr
Missions	RSTA, BDA, coms relay, NBC sensing	Sensor emplacement
Payload	- EO (B/W -> colour) - microphones - NBC sniffer	Radar jammer
Image Tx	near-real-time	not applicable
Type of engine	- gas turbine - electric - electrostrictive polymer muscles - piezoelectric actuators - silicon turbojet - kerosene internal combustion engine	electric
Launch methods	- hand-launch - munitions launch - platform-launch	- hand-launch - from larger UAV
Range	9,66 km	3 - 5 km
Endurance	20 min - 2 hours	20 minutes
Speed	64 - 80 km/h	32 - 64 km/h

- SRI International and the University of Toronto received a US $ 590.000 contract (which could grow to US $ 2 million over 36 months) for the development of a +/- 15,24 cm ornithopter μUAV powered by electrostrictive polymer articial muscles.
- Vanderbilt University received a contract to mimic insect flight using piezoelectric actuators to resonate a thin metallic structure that actuates the wings. The contract could be worth US $ 738.000 if options are excercised.
- California Institute of Technology (teamed with AeroVironment and the University of California-Los Angeles) received a US $ 1,8 million contract (if options are excercised) to study and possibly fly a 10 gram flapping "Microbat", which will carry microphone arrays for acoustic homing in on sounds.
- Massachusetts Institute of Technology received a contract that could be worth US $ 2 million to develop a shirt button-sized hyrogen-fueled silicon micro turbojet weighing 1 gram, producing 13 grams of thrust to propel a 50 gram μUAV.
- D-Star Engineering received a contract with a value of US $ 650.000 (if options are excercised) to make a kerosene internal combustion engine, which could possibly be a muffled ceramic diesel engine weighing 20 g, measuring 2 cm and producing 80 watt shaft power.
- Technology in Blacksburg Inc. received a contract with an initial value of US $ 150.000 (US $ 950.000 with options) to explore thermoelectric generators to recover waste heat from inefficient small engines.

The NLR has specified that their μUAVs can have a wingspan of 15,24 to 20,32 cm (6-8 inches); they are expected to weigh 50 to 100 gram, carry a 15 gram payload and fly for up to 20 minutes at 32 to 64 km/h using an electric engine. Fuel cells under development at DARPA will provide higher energy density and power levels than the lithium batteries currently available. The US Navy envisions launching their micro UAVs either by hand or from a larger UAV, which will then fly autonomously with a radar jamming payload (still under development) and land unnoticed on the radar dish. The first flight demonstrations are planned in 2001. The NRL's Tactical Electronic Warfare Division is responsible for the design of the aerial vehicle and systems integration. It has designed a twin engine Micro Tactical Expendable UAV to meet DARPA's design parameters.

The US Office of Naval Research is also sponsoring, in collaboration with DARPA, an investigation into insect aerodynamics by the University of California. The goal of this five-year programme is to develop a robotic fly with a diameter of 5 to 10 mm, that can transit over a short distance and maintain a stable hover.

The following US companies currently have Micro UAV development programmes underway:

	Designation	*Type of Airframe*
AeroVironment	BlackWidow	Non-hovering disk
AeroVironment, UCLA & CIT	Microbat	Flapping wing
Aerodyne	Hyperav	Hovering disk
D-Star	D'Spyfly	Flying wing
Georgia Tech	Entomopter	Flapping wing
Lutronix	Kolibri	Rotary wing
MLB	- Bat	Flying wing
	- Micro Dot	Non-hovering disk
	- Trochoid	Flying wing
Sander, Lockheed Martin & GE	- MicroStar	Fixed wing
	- MiniStar	Fixed wing
SRI Internat. & Univ. of Toronto	Mentor	Flapping wing
Vanderbilt University	?	Winged crawling insect

AeroVironment has reported flights of up to 20 minutes with its Black Widow.

As can be seen from the aforementioned, there is considerable acitivity in the US in this field, and universities are heavily involved. The funding is principally being put up by DARPA and the Office of Naval Research.

In Europe there is as yet no government funded micro UAV-related research and development programme with a clear objective.

However, the French Ministry of Defence (DGA) is planning to shortly initiate and fund (possibly jointly with other European MoDs) an European-wide competition relative to the development of micro UAVs. Teams composed of universities, industry and R&D institutes will be given a detailed scenario for which micro UAVs are to be developed. It is to be hoped that this will chrystalize R&D in this field in Europe, as the commercial and financial implications of the technological spin-offs could be extremely rewarding, aa the emerging technologies could have multiple other military and non-military applications.

LOW ALTITUDE LONG ENDURANCE UAVs

This is a relatively small category of UAVs. However, due to the exceptional performance of these aircraft, they are considered to warrant a separate classification. Currently, the operational systems that belong to this category are:

- Aerosonde	Aerosonde Robotic Aircraft	Australia
- Laima	Insitu Group	USA
- Pelican	US Navy Center for Interdisciplinary Remotely Piloted Aircraft (CIRPAS), USA	

All three of these aircraft are used for meteorology measurements.

Aerosonde has been developed by Aerosonde Robotic Aircraft (formerly known as EES), Australia in cooperation with the US Naval Research Laboratory. This 15 kg UAV is used for over-ocean meteorological sensing purposes in Australia by the Australian Bureau of Meteorology and in Taiwan by that country's Central Weather Bureau, and has also flown such missions much out Japan. It's extremely long endurance of 32 hours is made possible by a specially modified single-cylinder four-stroke engine, driving a two-blade fixed- pitch pusher propeller. The consumption of this aircraft is exceptionally low. As illustration, it should be mentioned that this aircraft

can stay aloft for 32 hours with only seven litres of low lead Avgas 100.

Laima is the American cousin of the Australian Aerosonde, produced by Insitu Group. This UAV has been operated on behalf of the World Health Organization, the US Office of Naval Research, the US National Oceanic and Atmospheric Administration, US de^partment of Energy and the US National Weather Serice. In 1998 Laima was the first UAV to cross the Atlantic from Canada to the United Kingdom (Hebrides). Both Laima and Aerosonde could quite possibly change the way weather is currently forecast, and play a very important role in improving hurricane and storm prediction..

Pelican is a modified Cessna 337 Skymaster (deletion of nose-mounted engine & replacement of rear engine by a more powerful one) that was developed by the US Office of Naval Research for low-altitude long endurance atmospheric and oceanographic sampling, with the support of NASA's Environmental Research Aircraft and Sensor Technology (ERAST) programme. General Atomics Aeronautical, USA, under contract to CIRPAS integrated the Predator flight control package into the aircraft. The aircraft is flown by means of CIRPAS's Predator ground control station.

OPTIONALLY PILOTED AIRCRAFT

Optionally or alternatively piloted UAVs (OP.UAV) are existing certified manned aircraft, which have been fitted with the necessary control system, thereby turning them into aircraft that can be operated without a pilot. Such aircraft can be fixed or rotary wing aircraft. The following OP.UAV examples can be mentioned:

CM-44	fixed wing	California Microwave, USA
Heliot	rotary wing	CAC Systèmes & EDT, France & Dragonfly , Italy
K-Max	rotary wing	Kaman, USA
Pelican	fixed wing	CIRPAS, USA
Vigilante	rotary wing	SAIC, USA

There are also several studies underway in this area in Europe concerning the droning of ultralights and high-flying research aircraft. Optionally piloted aircraft have a number of advantages:

- the airframe is relatively inexpensive;
- the payload capacity is relatively high;
- because they are certified, they can be flown in the same airspace as a piloted aircraft, as long as a pilot is onboard and the aircraft can comply with all existing rules and regulations (See & Avoid);
- they can be used as a testbed to evaluate and validate various types of UAV payloads;
- and possibly even more important, they can be used to used to prove datalink and command & control link reliability for airworthiness certification purposes, which should help build user confidence and acceptance, which is essential, if the UAV market is to expand.

It is mentionworthy, that CAC Systèmes, France has been awarded a contract by the French INTRA Group for a Heliot UAV system. This optionally piloted rotary wing aircraft is to be used as a surveillance and command & control relay UAV by INTRA, a French organization responsible to monitor nuclear facilities in the case of an accident. To accomplish this INTRA uses a number of different unmanned ground vehicles (UGVs) for various intervention and surveillance purposes; these UGVs will now be controlled via Heliot.

The Vigilante VTOL UAV under development by SAIC, USA, and one of the contenders for the US naval VTOL UAV requirement, is also based on a manned helicopter.

The K-Max (Kaman, USA) will be evaluated by the US Marine Corps as an autonomous UAV for delivering externally slung loads during resupply missions.

OP.UAVs could quite possibly become in important instrument in the critical airworthiness certification process, and will most probably play a required intermediate role in the UCAV development process.

UCAVs

The far rumblings of uninhabited combat aerial vehicles (UCAVs) are now also starting to be heard. This is still a rather obscure area, due to the classified nature of these development programmes, but a number of UCAV-related studies, evaluations and demonstrations are taking place. Basically, two types of UCAVs being considered :
a) aircraft-based designs;
b) (cruise) missile-based designs.

The driving forces behind the interest in UCAVs can be distilled down to the following :

- they are less expensive than manned aircraft (less maintenance, no pilot & no pilot-related safety);
- they are less expensive than expendable cruise missiles (they are reusable);
- they are capable of very high manoeuvrability & speed (much more than a pilot could support).

The roles for which UCAVs are most cited are the suppression of enemy air defences (SEAD) and deep strike missions in heavily defended sectors. In such roles UCAVs are to be seen as support systems for manned aircraft and not replacements. They are envisioned to be operated either from a ground or an airborne control station, manned combat aircraft, or a combination of these. UCAVs will require to be able to transmit large volumes of real-time and secure data to their operators; they will be required to be fitted with multiple and powerful imaging systems linked to automatic high speed target identification systems.

In 1997, the UK MoD launched a US $ 57 million study of options relative to the Future Offensive Air System (FOAS), which is scheduled to replace the Tornado fighter, beginning in 2015. UCAVs are one of the options considered. The MoD has awarded a number of study contracts for the definition of UCAVs.

In 1997 Lockheed Martin and Tracor Inc. (now BAe, UK) announced their collaboration to drone a F-16 fighter (OP.UAV?) and use this aircraft as a UCAV surrogate for further technology development.

In 1997 the US Navy selected Lockheed Martin to develop a concept for a submarine-launched VTOL UCAV to be launched from ballistic missile tubes. This is one of the UCAV concepts being pursued by the Naval Air Systems Command.

In 1998 the French MoD-DGA and the US Air Force formed a teaming arrangement to develop flight control and flight management technologies that are to allow the interoperability of manned aircraft and UCAVs for strike missions.

In 1998 DARPA and the US Air Force awarded a US $ 4 million 10-month study contract to four contractors (Lockheed Martin Tactical Aircraft Systems, Northrop Grumman, Raytheon, and Boeing Phantom Works) as part of an Advanced Technology Demonstration Pro-

gramme to develop a UCAV used specifically for the suppression of enemy air defences and deep strike missions. In 1999, Boeing received a contract to build two demonstrator UCAVs and a mission control station; flight testing was scheduled to commence in 2001; it has been indicated that the first flights could possibly even take place in 2000.

Dassault Aviation, France is undertaking UCAV-related study work in cooperation with Boeing. Saab, Sweden also has several ongoing auto-financed UCAV-related studies.

It seems safe to state that UCAVs still have a long way to go before they can enter into service, and that not only technical hurdles have to be overcome, but that a number of ethical and moral issues also have to be dealt with. The current rules of engagement will also have to be adapted to take UCAVs into account.

Fig. XI - MILITARY UAV MISSIONS

CURRENT
- Reconnaissance
- Surveillance
- Target acquisition
- Decoy

FUTURE
- Aerial mine detection
- Artillery correction
- Battle damage assessment
- Battlement management
- Comms & data relay
- Command & control relay
- Digital mapping
- Electronic warfare
- Flight path recce
- NBC recce
- Perimetric surveillance
- Psychological warfare
- Radar jamming/saturation
- Remote sensor delivery
- SIGINT
- Target designation
- Treaty monitoring
- Urban warfare
- Offensive :
  - anti-radar
  - anti-vehicle
  - anti-ship
  - anti-structure

MILITARY MISSIONS

Currently, both tatctical and strategic UAV missions principally consist of:
- Reconnaissance
- Surveillance
- Target acquisition

Tactical UAVs have already been used to fulfill decoy and radar saturation roles (Allied Forces during Desert Storm); the the case of Israel this was the original purpose of UAVs. BAe Australia's Nulka is to enter service shortly as an anti-ship missile ship-launched decoy.

There are however many other missions that both tactical and strategic UAVs will possibly be used for in the future (*See Figure 11*). To a relatively large degree, the future roles that UAVs will be able to play will depend on the development and production of the payloads required to accomplish the indicated specific missions.

IMAGING PAYLOADS

Most of the future UAV missions depend for a large part on the development of the right sensors at the right price. As the cost of UAV missions, in military and financial terms, is very much in function of the required payload sensors, substantial R&D efforts and industry consolidation are taking place in this area. Figure 12 gives an overview of existing imaging payloads and ongoing developments in this area. Figure 13 details non-imaging payloads. Figure 14 details what imaging payloads are currently in use on what UAVs.

Better and Smaller

Advances in technology (e.g. non-cooled IR, hyperspectral imaging and downsized Synthetic Aperture Radar (SAR) sensors) and new detector elements (e.g. 3-5 μ InSb chips, Megapixel FPAs) are permitting ever increasing performance (bigger stand-off distances, higher sensitivity, higher resolution), as well as ever larger degrees of miniaturisation. Substantial advances in the fields of Electro-Optics (EO) and IR sensors have been made, and apparently the miniaturisation of the optics is one of the last remaining challenges. These developments have made it possible to produce relatively small (in weight and dimension) mono and multiple sensor (EO, IR, laser range-finder) payloads, which are becoming the imaging sensors of choice for tactical UAVs.

The increasing interest in regimental/brigade level close range UAVs (e.g. Luna-EMT, Germany, Observer-DERA & Cranfield Aerospace & Tasuma/UK, Pointer-AeroVironment/USA, Vigiplane and Vigilant 2000-Techno-Sud/France) and the rather limited payload capacity of such aerial vehicles is driving manufacturers to develop and produce new lightweight sensors, often incorporating new technologies and very novel concepts.

Fig. XII - IMAGING PAYLOADS

CURRENT
EO
IR (3-5 & 8-12μ)
EO/IR
EO/LRF
IR/LRF
EO/IR/LRF
SAR
SAR/MTI

ONGOING DEVELOPMENTS
IR (3-5μ)
Uncooled IR
Miniature sensors
Micro sensors
Multi-spectral
Down-sized SAR
Miniature SAR
LIDAR
Foliage penetrating radar
Hyperspectral imagers
Large format FPAs
Sensor marinization
Automatic target recognition

Synthetic Aperture Radar

Recent developments in hard- and software are permitting synthetic aperture radar (SAR) (with and without moving target indication) to prove their operational value as true all-weather sensors in roles including surveillance, target acquisition, mapping, and treaty verification. Advances in technology will shortly see SAR capabilities expand to include e.g. foliage penetration and mine detection. For the moment, SAR is only operational on the Predator (MALE) UAV, but as developments in this field are customer-driven and all military users require all-weather capability, it will only be a question of time until SAR finds its way onto the smaller tactical UAVs.

The CL289 sensor upgrade programme (Sword: 25 kg), a collaborative programme between Thomson-CSF Detexis and Dornier, Germany, and the development of the Lynx SAR (50 kg), funded and carried out by General Atomics, USA, are prime examples of the ongoing effort to down-scale SAR. It is also of interest to note that the Ministries of Defence of Belgium, Denmark, Finland, the Netherlands and Sweden have all designated SAR as necessary options for future upgrades of their UAVs (purchased and still to be purchased).

Figure XIII
NON-IMAGING PAYLOADS

Active RCS simulation
Communications jammer
Communications relay
Land-mine detection & identification
Sea-mine detection & identification
Radar jammer
Radiation seekers
SIGINT
Dispensors for:
- crowd control devices
- pamphlets
- ordnance
- meteorological sondes
- remote sensors

Non-imaging Payloads

The non-imaging payloads indicated herewith are currently being designed, developed and evaluated for use on different types of UAVs in a number of countries. Active research and evaluation,

Figure XIV - WHO USES, OR WILL USE, WHAT PAYLOAD ON WHAT UAV ?

DEPLOYING COUNTRY	UAV SYSTEM	UAV SYSTEM MANUFACTURER	PAYLOAD DESIGNAT.	TYPE OF SENSOR(S)	PAYLOAD MANUFACTURERS
Algeria	Seeker II	Kentron, South Africa	Goshawk	EO/IR 2nd gen	Cumulus, South Africa
Belgium	Epervier Hunter	MBLE Défense †, Belgium IAI, Israel & Eagle consort.	AA3-70/6-62 MOSP ?	EO still camera EO/IR	Omera/Thomson, France IAI-Tamam, Israel
Bahrain	Exdrone	BAI Aerosystems, USA	PTZ	EO & EO/IR	BAI Aerosystems, USA
Bulgaria	Vigilant	Techno-Sud Ind., France	unnamed	EO	Techno-Sud Ind., France
Czech Rep.	Sojka III	VTUL a PVO, Czech Rep.	Camelia	IR linescanner	Intertechnique, France
Denmark	Sperwer	Sagem, France	Hesis	EO/IR	Sagem, France
Finland	Ranger	Oerlikon-Contraves, Switzerl	MOSP	EO/IR	IAI-Tamam, Israel
France	CL289 Crecerelle Fox MLCS Hunter Vigilant	Aérospatiale/Dornier Sagem, France CAC Systèmes IAI, Israe& TRW, USA Thomson & Techno-Sud Ind.	KRb8/24D, or Corsaire Sword unnamed Cyclope 2000 unnamed - 445G MK III - Camelia - GlobalScan Mosp 3000 - unnamed - Sophie	EO, or IR linescan SAR/MTI CCD linescanner IR linescanner static CCD (pilot) EO/IR IR linescanner HD EO linescanner EO/IR - CCD - IR	Zeiss, Germany Sagem (SAT), France Thomson/F & Dornier/D SAT, Sagem SAT, France SAT, France Inframetrics, USA Intertechnique, France Cose, France IAI-Tamam, Israel Techno-Sud Ind., France Thomson-CSF, France
Germany	CL289 Taifun Brevel (KZO) LUNA	Dornier & Aérospatiale STN Atlas STN Atlas & Matra EMT, Germany	KRb8/24D, or Corsaire upgrade Taifun Isos 2000 P286D Attica	EO, or IR linescan SAR/MTI imaging radar IR IR + EO	Zeiss, Germany Sagem (SAT), France Dornier/Thomson Daimler-Benz, Germany Zeiss, Germany Zeiss, Germany
India	Nishant Searcher	ADE, Bengalore, India IAI, Israel	? Mosp	EO or IR EO & IR	local production IAI-Tamam, Israel
Indonesia	Fox AT2 Heliot	CAC Systèmes, France	- GlobalScan - Camelia - 445G MK II	- HD EO linscanner - IR linescanner - EO/IR	Cose, France Intertechnique, France Inframetrics, USA
Israel	Scout Searcher Hermes 450S	IAI, Israel IAI, Israel Silver Arrow, Israel	various various MOSP	various various EO/IR	Controp, Israel IAI-Tamam, Israel IAI-Tamam, Israel
Italy	Mirach 20 Mirach 26 Mirach 150	Meteor, Italy Meteor, Italy Meteor, Italy	? ? ?	CCD or IR CCD/LLLCCD/IR CCD/IRLS/Panoramic or High Alt. Camera	AquaTV or Galileo, Italy FIAR/Rank-Pullin/Galileo FIAR,Italy/BAe,UK/Vinten or Vinten/UK
Netherlands	Sperwer LUNA	Sagem, France EMT, Germany	Hesis P286D Attica	EO/IR or EO IR + EO	Sagem, France Zeiss, Germany
Romania	Shadow 600 Vigilant	AAI, USA Techno-Sud Ind., France	445G MK II unnamed	EO/IR EO	Inframetrics, USA Techno-Sud Ind., France
Singapore	Scout Searcher	IAI, Israel IAI, Israel	various various	various various	Controp & Tamam,Israel Controp & Tamam,Israel
South Africa	Seeker Vulture	Kentron, South Africa ATE, South Africa	Goshawk ODS	EO/IR 1st gen EO	Cumulus, South Africa ATE & M-Tek, S. Africa
South Korea	Bijo Harpy Searcher	Daewoo IAI, Israel IAI, Israel	undecided ? MOSP	EO/IR radar seeker EO/IR	undecided ?, Israel IAI-Tamam, Israel
Spain	Siva	INTA, Spain	MKD 400NDP	EO/IR	Tadiran, Israel
Sri Lanka	Scout	IAI, Israel	various ?	various ?	Controp or IAI, Israel
Sweden	Back-Pack Ugglan	Mission Technologies, USA Sagem, France	? unnamed	? EO/IR	? Sagem, France
Switzerland	Ranger	Oerlikon-Contraves,Switzerl.	MOSP	EO, IR, EO/IR	IAI-Tamam, Israel
Thailand	Searcher	IAI, Israel	MOSP	EO, IR	IAI-Tamam, Israel
Turkey	Gnat 750	General Atomics, USA	Model 12	EO or IR	Wescam, Canada
UAE (Abu Dhabi)	Seeker	Kentron, South Africa	Goshawk	EO/IR	Kentron, South Africa
UK	Phoenix	GEC Marconi Avionics, UK	MRT-S	IR	GEC Marconi Avionics
USA	Camcopter Darkstar Dragon Global Hawk Gnat 750 Hunter Outrider Pioneer Pointer Predator	Schiebel, Austria Lockheed & Boeing, USA BAI Aerosystems, USA Teledyne Ryan, USA General Atomics, USA TRW, USA & IAI, Israel Alliant Techsystems, USA Pioneer UAV, Inc/AAI Corp. Aerovironment, USA General Atomics, USA	445G MK III Tesar & CA-236 PTZ Hisar & unnamed 12DL Mosp Ultra 3000 or Pop 100 12DS ? - IRμCam Tesar & Skyball	EO/IR SAR EO linescanner EO SAR/MTI EO/IR EO & IR EO/IR EO/IR EO/IR EO/IR EO IR SAR/MTI 2xEO/IR	Inframetrics, USA Northrop, USA Recon/Optical, USA BAI Aerosystems,USA Hughes, USA Hughes, USA Wescam, Canada IAI-Tamam, Israel FLIR systems, USA IAI-Tamam, Israel Versatron, USA) ? Microcam Corp., USA Northrop, USA Versatron, USA

principally concentrated in the USA, is ongoing relative to the possibility of dispensing various devices from UAVs. This obviously also requires, in some cases, the development of the devices that are to be dispensed.

LAUNCH & RECOVERY

As can be concluded from the classification on the first page of this article, tactical fixed wing UAVs (excluding µ UAVs) can be split into two types :

· aircraft with fixed or retractable landing gear (IAI/Israel, Daewoo/South Korea, Kentron/South Africa, IAI and Silver Arrow/Israel, and the majority of the manufacturers in USA);

· aircraft launched by means of a launcher or RATO (Rocket Assisted Take-Off) and recoverable by parachute, in many cases with the help of airbags (all European systems, ATE/South Africa and a small number of US manufacturers).

LAUNCH SYSTEMS

Fixed or Retractable Landing Gear

The Israeli preference for wheeled UAVs most probably stems from the fact that Israel is a relatively small and narrow country with limited military and financial resources. The distances to its sensitive borders (Libanon, Syria) are relatively short and the Israeli Defence Force (IDF) does not traditionally project its forces far outside the country's borders for an extended period of time (S. Libanon is the exception). The short distance to the Forward Line Of Troops (FLOT) permits the IDF, or the Israeli manufacturer operating UAVs for the IDF, to launch their UAVs from established and secure airfields.

Figure XV - UAV Launch Methods

- **Hand-Launched**
- **Weapon-Launched**
- **Launcher:**
  - **Bungee cord**
  - **Hydraulic**
  - **Pneumatic**
  - **Atmospheric**
- **Rocket Assisted Take-Off (RATO):**
  - **Zero-length launcher**
  - **Mono-vehicle canister**
  - **Multiple vehicle canister**
- **Landing Gear & Wheels**
- **VTOL**
- **Aerial Launch:**
  - **from manned aircraft**
  - **from UAVs**
- **Torpedo or missile tube launched**

The US preference for wheeled tactical UAVs is said to be linked to their strategic requirement to be capable of global power projection on one side, and their desire to limit, as far as possible, the necessary logistical trail (no launchers, no parachutes), and is based on the assumption that overwhelming US military force will permit them to secure the infrastructure required for wheeled take-off and landings, irrespective of where they deploy. Out of all the UAV systems in service in the US, only Exdrone and Dragon UAVs, which are in service with the US Marine Corps, use a launcher. It should however be mentioned that the US military also has substantial experience with RATO for launching their UAVs (Pioneer and Hunter).

The tactical UAVs in the aforementioned countries tend to have fixed landing gear, whereas the larger medium altitude long endurance (MALE) and high altitude long endurance (HALE) UAVs have retractable landing gear. A number of manufacturers have equipped their landing gear with a remote controlled break system.

There is only one European Ministry of Defence (Belgium) that has opted for wheeled tactical UAVs (Hunter B). The single Hunter system procured by the French Ministry of Defence, which is of course also wheeled, should be seen as a one-off purchase of a test system for evaluation of payloads and operational concepts, and not as a system in operational military use.

Obviously, both fixed and retractable landing gear increase the weight of the aerial vehicle. The additional set-back of fixed landing gear is that they increase aerodynamic drag. Retractable landing gear take up considerable volume in the fuselage and the wings, which partially explains why they are used only on larger UAVs.

Some manufacturers have also experimented with launch dollies. These are wheeled trolleys on which the aircraft is placed; the aircraft can then take off under its own power, or in the case of smaller UAVs, the trolley is tracked by a high speed static winch, or even bungee cords. This method has now largely been abanded.

Launcher Systems

MALE and HALE UAVs can of course be launched so far from the FLOT, that the required airfields or roads are not normally a problem.

European, and most other military forces, however generally go out from the assumption that the roads or airfields in their countries, which may be required for launching wheeled tactical UAVs will not always be available to the rapidly moving troops in a war time situation. It is of interest to point out that the Belgian Ministry of Defence is the only European entity that has opted to equip its defence forces with a wheeled tactical UAV (Hunter), and that the Croatian Ministry of Defence has also expressed its preference for wheeled UAVs.

Future joint peacekeeping and multinational military operations, and the exposure of European military to the deployment of wheeled tactical and strategic UAVs by their coalition partners, may possibly influence this stance in the future.

UAV launchers can be divided into various categories:

· Bungee cord launchers (which are now largely being abandoned due to their poor performance in both hot and cold temperatures, the inconsistency in their launching speeds and the impossibility to precisely predefine launch speeds). Bungee cord launchers are, for the moment, still used for a number of small UAVs;

· Pneumatic/hydraulical launchers (Crecerelle, Exdrone & Dragon, Fox MLCS, Phoenix, Ranger, Shadow 200, Sperwer, Ugglan);

· Atmospheric launchers (Vulture, Super Vulture);

· RATO launchers can be divided into 3 types:
  - zero-length launchers (CL289, Harpy, Mirach 26, Pioneer);
  - mono-vehicle canister launch (Brevel, Tucan, Mücke);
  - multiple vehicle canister launch (Taifun).

In a 1998, the Crecerelle bungee cord launcher was replaced by a pneumatic launcher supplied by Sagem, France. In the programmed upgrade of the Mirach 26, the Italian MoD has the intention to abandon the RATO launch method and adopt launch by means of a pneumatic launcher. The Netherlands Army has purchased a pneumatic launcher from Robonic, Finland for the launch of their KD2R aerial targets. The targets services division of CAC Systèmes, France is also using a pneumatic launcher (OKT Norge, Norway) to launch their aerial targets.

In view of the systems mentioned above, it is of interest to note that there is currently only one company spe-

cialised in the design, development and production of pneumatic launchers in Europe (Robonic, Finland). One of the specific features of the Robonic series of launchers is that they can be disconnected easily from their transporting trucks and operated without the truck being present. This is accomplished by lowering four pneumatic legs on which the entire launcher rests and then jacking the launcher up, thereby permitting the truck to drive away from under the launcher frame. This system permits to use the truck for other purposes while the launcher is being used (or in storage).

Sagem, France has purchased the licence rights to the launcher developed by OKT Norge, Norway for the Sperwer tactical UAV and this is now produced in France.

The atmospheric launcher produced by ATE, South Africa is a rather unique system; instead of creating an overpressure to push a piston, the atmospheric launcher creates a vacuum in a cylinder, which pulls a piston in a sealed cylinder. The advantage of this system is said to be logistical (very few parts are submitted to wear and tear) and operational (aircraft can be launched at sea-level as well as relatively high altitudes).

A special mention should be made of the experience AAI Corp., USA has in the field of ship-launched (RATO – Rocket Assisted Take-Off) fixed wing UAVs. AAI Corp. has been involved with the Pioneer UAV from the onset, and has not only been responsible for the majority of the very many upgrades that have been made over the years, but also gained valuable operational experience during the Gulf War, when they established a forward base in Bahrain from where they serviced and reconditioned Pioneer UAVs, which were extensively launched from land-based bases, as well as from ships. Their ship-launch experience with Pioneer has made it possible for AAI Corp. to develop within a very short period of time, in reply to a requirement of the South Korean Navy, the fixed wing Shadow 400 (range: 200 km), which is ship-launched (by means of RATO) and ship-recoverable (by means of a recovery net on the rear deck).

RATOs have several disadvantages: they are added logistical problem; they pose a flammability hazard; they are rather expensive if not purchased in large quantities; they generate visible exhaust fumes and create a high infrared signature; and lastly, changing the payload on a UAV can implicate the necessity to realign the RATO(s). However, zero length launchers are relatively cheap and they make it possible to launch from confined areas (ships), unprepared terrain, and in the case of canister launch, launch preparations can be kept down to a minimum, which makes for a highly mobile system.

BAI Aerosystems in the USA has produced a pneumatic launcher based using commercial-of-the-shelf rodless cylinders for their Exdrone and Dragon UAVs. This launcher principal was proposed by the US Naval Surface Warfare Center to the US Naval research Lab, which funded the development of such a launcher for their electric Swallow UAV. The US Marine Corps then funded the development of a similar type of launcher for their Exdrones and Dragon UAVs; this launcher has now replaced the former pneumatic launchers, which shot out a steel piston pushing the UAV towards the sky. The flying steel piston was obviously a safety hazard.

Recovery

Recovery by means of parachute and airbag is gaining terrain for tactical systems (Brevel and Tucan and Mücke-STN Atlas/Germany, CL289-Aérospatiale/France and Dornier/Germany, Mirach-26-Meteor/Italy, Phoenix-GEC/UK, Sniper-Silver Arrow/Israel, Sperwer and Ugglan-Sagem/France, Vulture and Super Vulture-ATE/South Africa).

Figure XVI - UAV Recovery Methods

- **Belly-landing**
- **Skid-landing**
- **Net (ship- & ground-based)**
- **Wheel(s) : - without breaks**
  - **- with breaks**
  - **- with arresting hook**
- **Parachute : - standard**
  - **- parafoil**
  - **- dirigable parafoil**
- **Parachute & airbag**
- **VTOL**
- **Aerial recovery**

Several UAV manufacturers have equipped there wheeled aerial vehicles with emergency parachutes (AAI Corp.-Shadow 200 & 400 & 600, Alliant TechSystems-Outrider, General Atomics-Prowler II).

A number of UAV manufacturers (e.g. S-Tec-Sentry, Lear Astronics-SkyEye, Northrop Grumman-Starbird) have experimented with various types of parachutes (ram-air parafoils & dirigeable ram-air parafoils), as well as ram air gliding wings. Air-ram wings have even been experimented with as main wings for pusher engine powered payload vehicles. None of such types of parachutes have as yet been adopted and approved by a customer as a standard means of recovery. It is considered to be mentionworthy that mid-air retrieval of UAVs (and aerial targets) under parachute has had a long history in the USA.

Fixed wing aircraft with landing gear can be equipped with breaks on the landing systems (Shadow 600-AAI Corp./USA, and/or arresting hooks that grab an arresting cable laid out over the landing strip between two reels with mechanical break systems (Searcher- IAI/Israel).

Research is also ongoing to equip VTOL UAVs with a parachute recovery system as a safety option. As the recent accident with the CL327 in Australia has shown, auto-rotation cannot always be counted on. One of the solutions being investigated is to house a safety parachute in a rotor-head compartment, or in a cylindrical compartment in the top part of the rotor shaft.

The Pioneer UAV (Pioneer UAV Inc., USA) is the only UAV with substantial recovery experience using a shipborne (and land-based) net system. Recovering aircraft in this manner on a ship requires either exception operator experience, or an automatic recovery system, which guides the incoming aircraft with a high degree of precision into the recovery net.

For obvious reasons, the MALE & HALE UAVs will continue to be equipped with landing gear, which in some cases may be retractable. Butler Parachute Systems, Inc., USA has designed a parachute system consisting of a rocket extractor, a pilot parachute to provide positive main chute deployment until full line stretch is reached, and a main chute with an extended skirt tri-conical canopy with drive vents, for General Atomics Aeronautical Systems' Predator MALE UAV (for emergency recovery). Butler has designed and built similar parachute systems for the General Atomics GNAT and Altus UAVs.

The commercial use of UAVs over populated areas in most of the industrialised world, as well as the introduction of military UAVs into civilian airspace, will probably

impose, at least initially a more widespread use of parachute and airbag recovery systems on UAVs for safety purposes.

An All-In-One Concept

The FOX MLCS tactical UAV system (CAC Systèmes, France) is noteworthy for the fact that this compact self-contained air transportable system consists of three aerial vehicles, a pneumatic launcher, a UAV operator station, and an image interpreter station all housed on one single Mercedes-Benz truck. The system requires minimal manpower and can launch from any unprepared terrain; the aircraft are recovered by parachute. This cost-effective type of UAV system can most probably find an interesting market with developing countries, as well as with countries for which air transportability, mobility and rapid deployment are key issues.

Automatic Take-Off & Recovery Systems

It is now generally recognized, that the majority of the UAV accidents take place during the launch and recovery cycles, and that most can be attributed to operator failure. This fact is pushing manufacturers and users alike in the direction of fully automated systems.

A growing number of UAV systems are using automatic recovery systems. Various types of automatic take-off and landing systems exist e.g.: millimetre wave tracking radar and guidance systems (UCARS-UAV Common Automatic Recovery System, Sierra Nevada Corp., USA), a laser radar & video camera (RAPS-RPV Autoland Position Sensor, Swiss Aircraft and Systems Company, Switzerland). UCARS has been developed on initiative of the US Joint Program Office; its development started in 1990 and the system has been successfully used with a variety of UAVs (CL-227, Hunter, Pioneer, Predator). RAPS was originally developed for the Ranger UAV (Oerlikon-Contraves), but is also available to other UAV system integrators. Automatic recovery systems will play a major role for all future shipboard recoveries.

DATALINKS

Datalinks should become a major issue in the near future. Some of the pressing matters that have to be dealt with are: availibility, bandwidth, frequency, interoperability. It is not the objective of this article to deal with this topic in detail. However, it should be noted that this problematic situation has been recognized by NATO and is being addressed by a number of committees.

Figure XVII gives a recapitulation of the datalinks currently used.

POWER PLANTS

One of the most critical sub-systems of UAVs are the engines. The majority of the currently flying UAVs are equipped with two-stroke engines manufactured by:

- Aerrow, Canada
- Hirth, Germany
- Limback, Germany
- Meggitt Defence Systems, UK
- Moto Guzzi, Italy
- Quadra, USA
- Rotax, Austria
- Sachs, Germany
- UAV Engines Ltd, UK

Advanced Electronic Systems, United Arab Emirates (AES) has designed a two-stroke engine, which is being produced exclusively for them by Zanzottera Engines, Italy. These engines equipped the AES aerial targets and UAVs.

Turboshaft engines produced by Allison and Williams in the US are used for UAVs. A limited number of UAVs also uses turbojets produced by Allison/USA, Microturbo/France, Williams/USA.

Substantial R&D has been ongoing for some time now in the field of heavy fuel engines. There are several reasons for the interest in heavy fuel engines:

- they do not pose a logistical problem, as fuel is ready available;
- they do not pose as big a fire hazard;
- logic has it that they would be more robust.

Companies involved in this area include:

- General Atomics, USA
- Sonex Research Inc., USA
- Southwest Research Institute, USA & Evan Guy Enterprises, USA
- UAV Engines Ltd, UK

Eventhough advance has been slow and expensive, it now appears reasonable to assume that heavy fuel engines are indeed feasible and will not take too much longer to be fully validated and market-ready.

CIVILIAN & COMMERCIAL APPLICATIONS

The use of UAVs for non-military purposes is still in its infant shoes. However, there are a number of current applications that are mentionworthy.

By far the most widespread and intense use of commercial UAVs takes place in Japan, where VTOL UAVs are extensively used for crop spraying and fertilizing. The use of these VTOL UAVs falls under the jurisdiction of the Ministry of Agriculture; all the aircraft are remotely controlled by an operator and are restricted to flying in-sight (300 m max. distance from the operator), and at an altitude of less than 150 m. All operators are required to follow an official operator's course and obtain an operator's licence.

Agricultural use of VTOL UAVs is now also being envisaged in South Korea.

The earlier mentioned Aerosonde/Laima low altitude long endurance UAV is another example of the interesting possibilities that UAVs can be put to. It should be of interest to note that, in order to make the use of Aerosonde/Laima viable as a meteorological sensing tool, the cost price of the aircraft clearly had be at a very competitive level. At a unit fly-away price of approximately US $ 35.000, this UAV has met its goal. One wonders if the basic Aerosonde/Laima system could also not be used for other purposes such as remote bacteriological or chemical agent, or nuclear fall-out monitoring. Aerosonde/Laima has been authorized by the Australian Civil Aviation Safety Authority (CASA) to fly meteorological missions over Australian waters. It should be noted that CASA has drawn up specific rules and regulations to make the deployment of Aerosonde possible in Australia.

A substantial number of different UAVs are also being used for special effects in the cinema industry and for publicity purposes, as well as broadcast TV and aerial photography purposes. In this respect the following manufacturers can be cited:

- Aerocam R/C Flying Systems, USA
- BAI Aerosystems, USA
- Envol Images, France
- Moving-Cam S.A., Belgium
- Survey Copter, France

In this field, a distinction should be made between indoor and outdoor UAVs. Outdoors, VTOL UAVs are principally used, and indoors lighter-than-air UAVs seem to be the norm. All these systems are PCM remote controlled.

Figure XVII - DATA LINKS - UAV Systems With Operational Range of > 1000 m

DEPLOYING COUNTRY	UAV SYSTEM	STATUS In Serv.	On Order	UAV SYSTEM MANUFACTURER	DATALINKS C2 Up	Imagery Down	CIVILIAN APPLIC.
Australia	Aerosonde	♦		Aerosonde Robotic Aircraft			♦
Bahrain	Dragon		♦	BAI Aerosystems, USA			
Belgium	Epervier	†		MBLE Défense †, Belgium			
	Hunter B		♦	IAI, Israel & Eagle Cons., Belgium	C-band	C-band	
Bulgaria	Vigilant 2000	♦		Thomson & Techno-Sud Ind.,France	S-band	S-band	♦
Denmark	Sperwer	♦		Sagem, France	Ku-band	Ku-band	(♦)
Finland	Ranger		♦	Oerlikon-Contraves, Switzerland	UHF	L/S-band	
France	Fox MLCS		♦	CAC Systèmes, France	S-band	S-band	
	Heliot		♦	CAC Systèmes, France	S-band	S-band	♦
	CL289	♦		Aérospatiale & Dornier	Not appl.	Not appl.	
	Crecerelle	♦		Sagem, France	300-600 MHz	300-600 MHz	
	Hunter		♦	IAI, Israel & TRW, USA	C-band	C-band	
	Vigilant 2000		♦	Thomson & Techno-Sud Ind.	S-band	S-band	
Germany	CL289	♦		Dornier & Aérospatiale	Not appl.	Not appl.	
	KZO (Brevel)			STN Atlas, Germany	Ku-band	Ku-band	
	Taifun		♦	STN Atlas, Germany	?	?	
	LUNA	♦	♦	EMT, Germany	5 GHz	5 GHz	
India	Searcher		♦	IAI, Israel	C-band	C-band	
	Nishant			ADE-Bangalore, India	L-band	L-band	
International Coop. Dvpmt	Brevel	♦		Eurodrone (STN Atlas&Matra)	Ku-band	Ku-band	
	Tucan				C-band	C-band	
Israel	Scout	♦		IAI, Israel	C-band	C-band	
	Searcher	♦		IAI, Israel	C-band	C-band	
	Hermes 450S	♦		Silver Arrow, Israel	C/L-band	C/L-band	
Italy	Mirach 20	♦		Meteor, Italy	420 MHz	1500 MHz	
	Mirach 26	♦		Meteor, Italy	L & J-band	L & J-band	
	Mirach 150	♦		Meteor, Italy	L & J-band	L & J-band	
Netherlands	Sperwer	♦		Sagem, France	Ku-band	Ku-band	
	LUNA		♦	EMT, Germany	5 GHz	5 GHz	
Romania	Shadow 600	♦		AAI, USA	C-band	C-band	
	Vigilant	♦		Techno-Sud Ind.	S-band	S-band	♦
Singapore	Scout	♦		IAI, Israel	C-band	C-band	
	Searcher II	♦		IAI, Israel	C-band	C-band	
	Upcoming RFI			Undecided	?	?	
South Africa	Seeker	♦		Kentron, South Africa	UHF	C-band	(♦)
	Vulture		♦	ATE, South Africa	UHF	C-band	
South Korea	Bijo		♦	Daewoo	C-band	C-band	
	Searcher II	♦		IAI, Israel	C-band	C-band	
	Shadow 400		♦	AAI Corp., USA	C-band	C-band	
Spain	Siva		?	INTA, Spain	UHF	S-band	
Sri Lanka	Scout	†		IAI, Israel	C-band	C-band	
	Ongoing RFP			Undecided	?	?	
Sweden	RPG MK III	†		Techment, Sweden	L-band	L-band	
	APID		♦	Scandicraft Systems, Sweden	L-band	L-band	(♦)
	Ugglan	♦		Sagem, France	C-band	C-band	
Switzerland	Ranger	♦	♦	Oerlikon-Contraves,Switzerld.	UHF	L/S-band	
Thailand	Searcher II		♦	IAI, Israel	C-band	C-band	
Turkey	Gnat 750	♦		General Atomics, USA	C-band	C-band	
	Upcoming RFP			Undecided	?	?	
UAE-AbuDhabi	Seeker	♦		Kentron, South Africa	UHF	C-band	
UK	Phoenix	♦		GEC Marconi Avionics, UK	Ku-band	?	
USA	Camcopter	♦		Schiebel, Austria	S-band	S-band	♦
USA	Darkstar	†		Lockheed & Boeing, USA	UHF/MilSatCom Ku-band/SatCom CDL/LOS X-band CDL/LOS	Ku-band/SatCom X-band/SatCom	
	Exdrone	♦		BAI Aerosystems, USA	UHF	D-band	
	Global Hawk	♦		Teledyne Ryan, USA	UHF UHF/MilSatCom CDL/LOS Ku-band/SatCom	Ku-band/SatCom X-band CDL/LOS	
	Hunter	†		TRW, USA & IAI, Israel	C-band	C-band/LOS	
	Outrider	†		Alliant Techsystems, USA	C-band	C-band/LOS & UHF	
	Pioneer	♦		Pioneer UAV, Inc/AAI Corp.	C-band LOS & UHF	C-band/LOS	
	Sentry	♦		S-Tec Corp.	S- or C-band	S- or C-band	
	Pointer	♦		Aerovironment, USA	?	?	
	Gnat 750	♦		General Atomics, USA	C-band/LOS	C-band	
	Predator	♦	♦	General Atomics, USA	UHF/MilSatCom C-band/LOS Ku-CDL	UHF/MilQSatCom Ku-band SatCom	

An electric powered lighter-than-air indoor UAV, developed and produced by Envol Images has been used for filming indoor swimming races. This brought an unexpected bonus to the swimming trainers: the top view of evolving swimmers made it possible to distinctly see body movements from a new angle, which resulted in making it possible to correct errors unknown up to that point in time, which in turn made it possible to achieve faster times. Envol Images and Moving-Cam have been supplying aerial imagery services to TV broadcasters, the publicity and cinema industry for a number of years. The Sultan of Oman's birthday parade has been broadcast live in Oman from a VTOL UAV developed and flown by Envol Images. BAI Aerosystems has flown its Javelin over public beaches for local TV stations. In all of these cases, the UAV manufacturer has been operating the system as a service to its customer.
Survey Copter, however, has developed and supplied a substantial number of its VTOL UAV systems to international operators for commercial use in their countries (aerial photography, aerial surveys).

A number of companies are investing the use of UAVs for dull and slightly dangerous mission such as powerline verfication.

The Swedish Wallenberg foundation is financing a research project which will investigate the use of VTOL UAVs for traffic surveillance purposes.

The French Groupe INTRA, an organization specialized in intervening in the case of a nuclear mishap inside and outside of France (which has the highest density of nuclear reactors of any country in the world), operates a fleet of various remote controlled ground vehicles for highly specific tasks. In order to be able to control these UGVs from a safe distance, Groupe INTRA has contracted CAC Systèmes, France to supply a Heliot VTOL UAV to act as an airborne control relay, and double as an airborne surveillance platform.

In the fight against illegal immigrants and drug smugglers, UAVs have been used by the US authorities along the southern border of the USA, and in Columbia.

The South African Air Force operates Seeker UAVs on a regular basis for the South African Ministry of Interior for border control purposes and with the specific task of detecting illegal immigrants, pinpointing them and then making it possible for police forces to intercept such immigrants. The SAAF have also operated Seeker during elections in South Africa to monitor crowds.

In its effort to maintain a balanced game population (in accordance with available food supplies), the South African Kruger Game Reserve, regularly counts the large animals in the park. This is done from helicopters. These same helicopters are also used for culling the animals when there are too many of them. The animals have now learned to hide when they hear a helicopter, and consequently they are ever more difficult to count. The use of UAVs is now being consider to detect and count the larger game.

In several countries the tuna industry has expressed keen interest to use UAVs to survey the ocean surface and track down schools of tuna (which in many cases is currently being done by manned helicopters).

The Baltic Watch project in Scandinavia is looking into the possibility of using UAVs to monitor the Baltic Sea and detect pollution, as well as for search and rescue missions.

High altitude long endurance UAVs of various types are being considered as surrogate low altitude satelites for telecommunications and television relay. As these aircraft will have to stay airborne for extended periods of time (weeks-months) alternative power sources such as solar power (Proteus-Scaled Composites, USA)(Pathfinder-AeroVironment, USA) and microwave power (SHARP-Communications Research Centre, Canada) beamed from the ground have been investigated. Angels Technologies Corp, USA has been announced as the first commercial customer of Proteus, and plans to use the aircraft for broadband microwave communications and cellular telephone networks. The SHARP (Stationary High Altitude Relay Platform) has been reported to highly interest China for cellular telephone networks.

Herewith following is a list of ***non-commercial*** some applications for which UAVs are or could be used or considered. The underlined applications are either already taking place, or are being seriously considered:

Civil Defence Organisations
- disaster area surveys & assessment
- communication relays

Forestry Services
- surveillance of forests / plant growth
- <u>fire control</u>
- mapping

National Weather Service
- atmospheric sampling
- <u>meteorology (hurrican prediction)</u>

National & Regional Meteorology Services
- avalanche control
- temperature & humidity monitoring

Ministry of Agriculture (Fish & Wildlife Authorities)
- agricultural monitoring
- river & estuary surveys / illegal waste disposal
- wildlife tracking & accounting
- <u>mapping</u>
- counter poaching control
- fishing law enforcement

Electricity Authorities
- <u>monitoring nuclear facilities</u>
- hazardous waste dump surveys
- power line verification

Customs Authorities
- <u>counter narcotics control</u>
- <u>counter smuggling control</u>

Ministry of Interior, National & Local Police
- <u>anti-terrorist intervention back-up</u>
- <u>counter narcotics surveillance</u>
- riot control - crowd control - border patrol
- area surveillance - <u>traffic control</u>
- <u>search & rescue</u>
- <u>emergency relief surveys</u>

Postal Services
- urgent package delivery in remote areas

Ministry of Environment
- air sampling
- hazardous waste dump surveys
- <u>forest fire detection</u>
- <u>inshore pollution detection</u>

Ministry of Transport
- <u>traffic & highway surveys & monitoring</u>
- mapping
- dike & dam inspection

Coast Guard
- surveillance for counter narcotics
- <u>illegal alien intrusion detection</u>
- illegal fishing control
- <u>national security threat surveys</u>

- search & rescue missions
- illegal ship's bilge oil dumping control

Civil Aviation Authorities
- noise measuremt for A/C certif. purposes

Red Cross, Red Crescent, NGOs
- natural disaster area surveys & assesment
- mine detection & indetification
- emergency relief surveys
- communication relays
- rapid delivery of emergency supplies

World Wildlife Fund
- rain forest canopy research
- natural reserve surveillance
- wildlife tracking & verification
- poaching control

Research Institutes
- marine environmental research
- meteorolgy research
- atmospheric research
- climatolgy research
- pollution related research

Commercial applications for UAVs can include:

Telecommunications Industry
- telecommunications relay

TV Industry
- pay-for-what-you-watch local TV coverage

News Casting
- news, sports & special events

Publicity Services
- television commercials
- promotional services
- flying publicity
- aerial photography

Cinema Industry
- aerial photography
- special effects

Electricity Distribution
- powerline verification

Real Estate
- aerial pictures for selling property
- aerial surveys

Surveying
- city & suburban planning

Farming & Ranching
- checking cattle
- fence line verification
- crop spraying (pesticide & fertilizer)
- crop monitoring
- soil, moisture & pest monitoring
- insect sampling

Fishing Industry
- monitoring of fishing grounds
- search for fish concentrations (tuna)

Maritime
- monitoring shipping hazards
- search & rescue

Security
- surveillance
- perimeter control

Lumber Industry
- tree spotting
- growth control
- mapping
- fire control
- forestry survey
- log transport

Aerial observation of archeological sites

Oil & Mining Industry
- gas & oil pipeline monitoring
- radiometric airborne surveys for geologic mapping & mineral prospecting
- airborne monitoring of geothermal areas
- airborne magnetic & electromagnetic surveys

Railroads
- aerial monitoring of rail lines & trains

Ski resorts
- avalanche control
- search & rescue

Aeronautical Industry
- testing new airframe configurations & designs

MILITARY CHALLENGES

Subsequent to the Gulf War and more specifically the conflicts in Bosnia and Kosovo, the military forces of the NATO countries, and some non-NATO countries, have realized the importance of information dominance during such crisis periods and the potential offered by UAVs in this respect. The advantages offered by the use of MALE UAVs, and the fact that only the USA has such assets, was not lost on anybody; during these conflicts the European military was to a large extent dependant for its intelligence.

The current politically driven tendancy to aim for zero risk conflicts, as well as the objective of minimal collateral damage and casualties, minimizing fraticide and controlling the electromagnetic spectrum during conflicts, are some of the additional driving factors behind the growing military interest in UAVs, and MALE UAVs with their large stand-off distance in particular. The increase of regional conflicts, and joint or coalition military intervention, peacemaking or peacekeeping operations, along with the building of a European military capacity, is making interoperability a major issue.

To sustain the interest in UAVs, the acquisition and ownership cost of these assets must come down, and this will definately implicate an increasing use of commercial technology. To reach this goal, a closer relationship between the military planners and industry is required; the military should find ways to implicate industry in the system definition phase at an earlier stage than currently is the case, and thereby avoid creating unrealistic requirements and permitting industry to take a phased approach to UAV system development.

The European military now have the major task of updating their UAV requirements to also incorporate MALE UAVs, deciding their operational requirements, evaluating existing systems, defining the required budgets, obtaining the required funding, weighing the interest to develop the required assets (or certain critical subsystems) on a national level, against a multi-national (European) development, and against purchasing the existing Predator system. In light of the current drive towards a European military union, such a decision should preferably be made in consultation with the other European partners. The problems of integrating MALE UAVs, and possibly at a later stage HALE UAVs, with the other military land, sea and space intelligence assets should also not be taken lightly.

Continued and increased use of UAVs in all categories by the military will hinge for a large part on finding solutions to the current problems related to UAV airworthiness and air traffic management. Once again these problems can only be solved, if a cooperative effort is made by the European military authorities and industry, on a national and multi-national basis, implicating as much as possible existing organizations and agencies with expertise in the relative fields.

EVOLUTIONARY MARKET

Today most military UAVs are used in the reconnaissance, surveillance and target acquisition roles. But as has been pointed out in this paper, there is a substantial amount of additional roles they will be fulfilling in the near future.

Between now and 2005 micro UAVs will start to come on steam, intelligent offensive UAVs will start showing up, VTOL UAVs in various categories will see the daylight, the use of UAVs as telecommunications relay will become a more wide spread reality, and many of the current reliability and operational robustness issues will start to be solved. More cost-effective solutions will be found and substantial strides will be made thanks to emerging technologies. Substantial advances should also be made in the fields of UAV-related airworthiness and air traffic management. This will build confidence with the current and upcoming users and should increase the degree of acceptance of UAVs, which should result in new concepts of operation starting to be defined. The coming five years will probably also see an increased use of UAVs for non-military purposes.

During the period between 2005 and 2010 airworthiness and air traffic management rules and regulations should start to firm up, currently emerging technologies should be mature, new rules of engagement should start to see the light, the acceptance of UAVs by users and the general public should start to become reality, armed UAVs should start coming into service, UCAVs should start to become a reality, and there should be an ever increasing use of commercial UAVs. It is envisaged that during this period UAVs will start to be deployed on a substantially larger scale.

UCAVs are expected to become an operational reality around 2020.

INDUSTRY CHALLENGES

In all the aforementioned military and non-military applications and scenarios, UAVs can only be considered as a viable alternative, if industry can successfully tackle the following issues:

Flight in Controlled Airspace

This is the all-conditioning factor. It order to make this possible, the first step is to develop acceptable airworthiness norms. The initiative to develop such norms should go out from industry, in co-ordination with the current military and potential future users. This should be initiated on a national level, and coordinated on a pan-European and worldwide level. It would appear logical that the first step is to form national working groups to deal with this issue and to put in place a structure which will permit the co-ordination of these working groups.

Safety & Reliability

Industry has to clearly demonstrate the safety and reliability of its UAV systems, and its critical subsystems. The current operational robustness has to be improved and ways have to be found to deal with such critical issues as system software evaluation and validation.

Lower Operational Costs

The acquisition price, as well as the operational costs have to be lowered to such a level that UAVs will be competitive with manned aircraft. This will most probably also mean a more intensive use of commercial off-the-shelf components.

Development Funding

Development funding from national governmental and European Union sources should be sought, and a higher degree of international cooperation should be aimed for. The potential spin-offs of UAV-related R&D should be more clearly highlighted to potential investors and goverment authorities. Universities should be more systematically involved in UAV-related research. It could be of interest to investigate the possibility of getting potential future UAV users involved with the financing of R&D at a very early stage.

The possibility of allotting a certain percentage of the government savings generated by downscaling and professionalizing the military forces in Europe to UAV-related research should be investigated. The current European tendancy to decrease Ministry of Defence funding of research and development programmes could cause substantial harm to the future of the European industrial base and widen the technology gap with the USA even further, if it is not reversed. The ongoing industry consolidation in Europe should also contribute to minimalising the national funding of funding of competitive programmes.

Increase Product Awareness

A substantial effort should be undertaken by industry to make the possible future commercial users more aware of the potential offered by UAVs, the technologies involved with their development, and the possible spin-offs. The awareness of UAVS by potential users can be increased by responsible coverage in the specialized and general public press, as well as on television, organizing educational briefings, inviting possible future users to UAV exhibitions and demonstrations, and bringing the issue of UAVs to the attention of technical universities, engineering schools, research institutes, as well as military academies.

Addressing Emerging Demand

Industry will have to adapt to dealing with customers other than the military. The approach to the commercial market is totally different from the military, and industry will have to adjust to be able to deal with potential applications of which it does not have much, or in some cases any, knowledge. This will be a period of bi-directional education, and will require industry to adapt to dealing with non-traditional customers who require relatively small numbers of UAVs. Only then will it be possible to understand the emerging demand.

The creation of a pan-European funded European UAV Institute, along similar lines as CIRPAS in the USA could be of interest to investigate.

A much closer relationship should be created by industry with its traditional military customer(s), with the intent to be involved by the military at a much earlier in the definition of their future operational requirements.

Legal, Ethical & Political Issues

The use of UAVs for many applications, including future military roles such as armed UAVs and UCAVs, will bring with it a necessity to deal with a substantial number of specific issues such as third party liability, operator responsibility, the implications of onboard intelligence with decision-making, and the legal implications of crossing over borders of friendly and non-friendly countries.

Strategic Alliances

It ishould by now be evident that only those companies that form international strategic alliances of one kind or another can hope to be amongst tomorrow's players in the UAV arena. It will be increasingly difficult for any single company to stay in rythm with the advances of technology and be able to auto-finance the development of tomorrow's UAV systems.

Spectrum Management

It is considered imperative that, in view of the limited availibility of frequency spectrum, UAV-related spectrum

management issues will be raised and addressed by European industry on a national, European and international level, with the competent authorities, through the existing organizations and agencies with responsibilities in this field.

Industry/University Partnership

Industry should endeavour to make more and better use of the research potential offered by the European universities. An interesting driver in this area could be the instigation of pan-European inter-university development competitions.

Customer Financing

Industry should endeavour to help find new and innovative ways to finance the purchase of UAV systems by potential military users and commercial operators.

UAV AIRWORTHINESS & AIR TRAFFIC MANAGEMENT

As has been pointed out earlier, the major restraint weighing on the commercial use of UAVs is the lack of airspace regulations, which is directly linked to the absence of internationally acceptable certification (airworthiness) norms relative to UAV systems, system software, sub-systems, and operator training, as well as the absence of regulations concerning command & control and datalink frequencies.

The recent conflicts in Bosnia and Kosovo also forced the military users to take notice of UAV-related air traffic management issues. With UAVs being launched out of Albania, Hungary and Macedonia to overfly Bosnia and Kosovo, posed a number of operational ATM problems, never before encountered in such a conflict. This situation has greatly contributed to focusing attention on UAV-related ATM.

The crucial issue of UAV-related ATM is now being seriously addressed by the civil aviation authorities on a national basis in a number of countries: Australia, Italy, Japan, Switzerland, UK. The Australian and Italian Civil Aviation Authorities have even drawn up a draft regulations for UAVs based on Joint Aviation Authorities' regulations pertaining to Very Light Aircraft (JAR-VLA). The Civil Aviation Safety Authority (CASA) of Australia has taken a risk management approach to the development of regulations for UAV operations, focusing on two areas: certification requirements and airspace requirements. For flights over populous areas, or within controlled areaspace, certification and operating requirements are the most demanding. However, for flights in remote areas, these requirements are relaxed.

The military authorities in Belgium, Denmark, Finland, France, Germany, Italy, The Netherlands, South Africa, Sweden, and UK are also addressing this issues seriously. But in practically all cases, the required rules and regulations are still lacking.

It is of interest to mention that the Royal Netherlands Army Materiel Command imposed the certification of the Sperwer UAV in the contract they signed with Sagem, France. At the time, no UAV airworthiness norms existed and it was made the responsibility of the Royal Netherlands Air Force's (RNAF) to define such norms. Basing themselves on the framework of the Joint Aviation Authorities' airworthiness norms for Very Light Aircraft (JAR-VLA), using their experience in the field of certifying manned military aircraft, and in close cooperation with Sagem, the RNAF has drawn up the world's first detailed UAV airworthiness norms. This ice-breaking process has been rather lengthy (3 years and still going), time-consuming, labor-intensive, expensive, and has necessitated the production of multiple volumes of documents, that were not foreseen at the onset.

NATO's Air Traffic Management Committee is deeply involved with UAV-related issues; the importance of finding an acceptable solution within the shortest possible time-frame, was driven home very strongly during the recent conflicts in Bosnia and Kosovo.

Surprisingly enough, the US FAA has not made any really noteworthy progress in this area, notwithstanding considerable lobbying efforts by US industry and the American Unmanned vehicles Systems Association.

At the recent international workshop on UAV-related air traffic management matters, that was held at EUROCONTROL headquarters in Brussels, Belgium on instigation of NATO, it was agreed that there is a legitimate right for UAVs to operate commercially, and that the non-existance of procedures/requirements for UAV operations should not restrict the development of UAVs. Indeed, the further development of UAVs should encourage and stimulate the development of the appropriate procedures.

EURO UVS' ACTIONS

Advances in the field of UAV-related airworthiness and air traffic management, will have far-reaching effects for current and future UAV operators, as well as industry, and requires a coordinated collaborative effort, involving the civilian aviation authorities, military representatives and industry on a national, European and international level. This fact has now been recognized by a number of organizations and has resulted in the following:

- On 9 June 1999, EURO UVS organized, in cooperation with NATO's Air Traffic Management Committee and in coordination with the Joint Aviation Authorities and EUROCONTROL, for the second consecutive year, an international workshop in Paris, France to deal with the critical topic of UAV airworthiness issues.Subsequent to this workshop, designated UAV Certif, which brought over 100 delegates from 17 countries together, a CD-ROM grouping a substantial number of international UAV-related airworthiness reference documents and opinion papers was produced by EURO UVS.
- On 13-15 October 1999, EUROCONTROL organized, together with NATO's Air Traffic Management Committee, and with the cooperation of EURO UVS, an international workshop on the topic of UAV-related Air Traffic Management (ATM). This event, designated UAV ATM, brought together 158 international military, civil aviation and industry delegates (NATO HQs, EUROCONTROL, Europe's Joint Aviation Authorities, FAA, all European countries, as well as Partnership For Peace states, Australia, and North America).
- UAVS, the United Kingdom's Unmanned Aerial Vehicle Systems Association has been founded by the leading UAV-related manufacturers in UK to deal with UAV-related airworthiness and ATM issues on a national level by liaising closely with UK civil aviation and military authorities.
- EURO UVS has instigated the creation of a French industry working group. WG-UAV/France has the intention to elaborate recommendations for submission to the French CAA (DGAC) relative to

UAV airworthiness issues. The work of this working group will be undertaken in close coordination with French national military and civil aviation authorities.

- EURO UVS is instigating similar working groups in Germany (together with Austria & Switzerland) (WG-UAV/Germany+Austria+Switzerland) and in Scandinavia (WG-UAV/Denmark+Finland+Norway+Sweden) before the end of 1999.
- EURO UVS has the intention to coordinate the activities between the various European working groups, and promote information exchange in this area internationally (Australia, Israel, Japan, North America, South Africa). Unless there is an element of harmonization between the European nations, and on a wider international scale, there is the potential for individual organizations and countries to go their own way and establish positions that may, subsequently, prove irreconcilable.
- After consultation with European military authorities, EURO UVS will be organizing before February 2000 an informal workshop for European military involved with UAVs. The objective of this workshop will be twofold:
  - to bring together European operational military authorities involved with UAVs and create an informal forum where they can exchange ideas and opinions;
  - to endeavour to create a consensus on the European military approach to UAV airworthiness and ATM issues at a very early stage.
- In June 2000, EURO UVS will be organizing, with the sponsorship of the international UAV community,and the participation of European Ministries of Defence, and in coordination with NATO, EUROCONTROL and the JAA, a major international technically informative conference and associated exhibition in the 'Palais de Congrès' in Paris, France. The activities at this event will be:
  - 14 June will be dedicated to reviewing UAV-related airworthiness and air traffic management issues, and will be a follow-up to the 1999 UAV Certif and UAV ATM events. During this day reports will be brought out by the various European working groups on their activities over the last 12 months. At this conference an updated version of the UAV Certif CD-ROM will be made available.
  - 15 June will feature presentations on military tactical and commercial fixed wing, lighter-than-air, and rotary wing UAVs.
  - 16 June will feature presentations on low altitude long endurance, medium & high altitude long endurance, and atmospheric UAVs.

INDUSTRY RECOMMENDATIONS

The general draft recommendations of the UAV ATM workshop held in Brussels (13-15 Oct. '99) were the following:

1- Encourage National Civil Aviation Administrations of the ECAC Members States in coordination with other interested agencies to initiate, where not yet done so, work towards the reviewing of national legal framework with the aim of permitting the safe and economic operation of UAVs.

2- With the view to the ultimate harmonisation of the certification requirements for UAVs to operate in ECAC Member States airpsace, invite EUROCONTROL, through its Airspace and Navigation Team of the EATMP to develop operational requirements for the operational and navigational capabilities of UAVs, and to consider the required ATM procedural and airspace management elements.

3- With the view to permitting UAV operations outside reserved airspace, invite national administrations and interested organizations, in cooperation with air users associations, to carefully study implications on ATS systems developments and airspace capacity.

4- With the view to the ultimate harmonization of the airworthiness and certification standards for UAVs to operate in European member states airspace, invite the JAA through its working arrangements to develop harmonized airworthiness requirements and certification processes.

5- NATO is to define the circumstances under which military UAVs would require to operate outside reserved (segregated) airspace.

6- NATO Document AC/92-D967 - «Guidance for Unlmanned Aerial Vehicles (UAV) Operations, Design Specification, Maintenance and Training of Human Resources» should be validated, updated, expanded and maintained as a useful reference document for further development.

7- To develop cooperation with ICAO in order to improve harmonization and the regional planning process.

8- To develop cooperation with FAA, Civil Aviation Safety Authority of Australia (CASA) and other interested non-European authorities in order to share experience and aim for an early harmonization of the certification requirements.

9- Having regard for the limited availability of frequency spectrum, it is vital that the spectrum management issues raised by the unique operating characteristics of UAVs are addressed. It is recommended that those organizations and agencies with responsibility at national and international levels for spectrum/frequency management be approached with a view to considering the impact that UAVs will have on the global communications infrastructure.

EURO UVS, with its wide base of European active industry and military members, and its constantly growing number of international associate members, hopes to be able to contribute significantly to the process, which will lead to the creation of UAV-related airworthiness and air traffic management rules and regulations. It this respect EURO UVS considers it has a valuable co-ordinating role to play in Europe, and to a certain extent also outside of Europe, in relation to the aforementioned, and welcomes input and suggestions from all concerned parties.